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BULLETIN
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American Association *of* Petroleum Geologists

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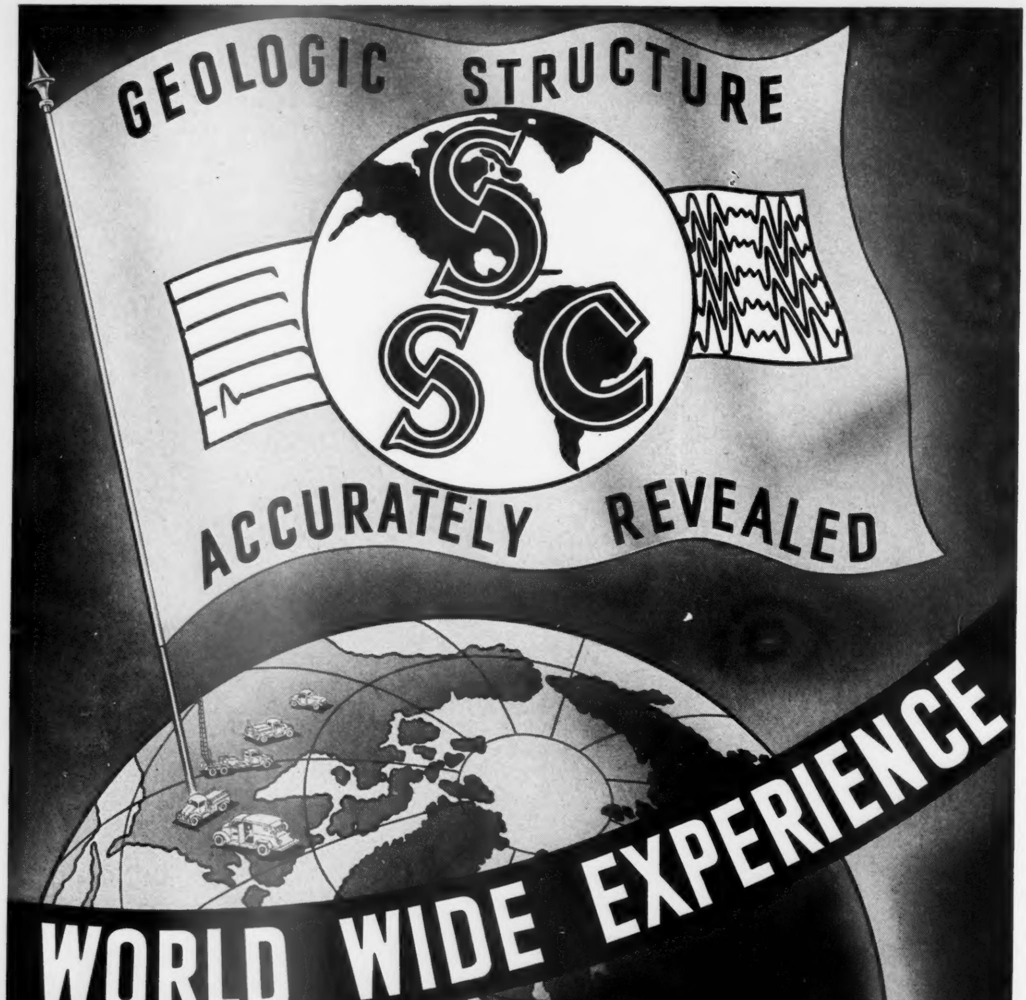
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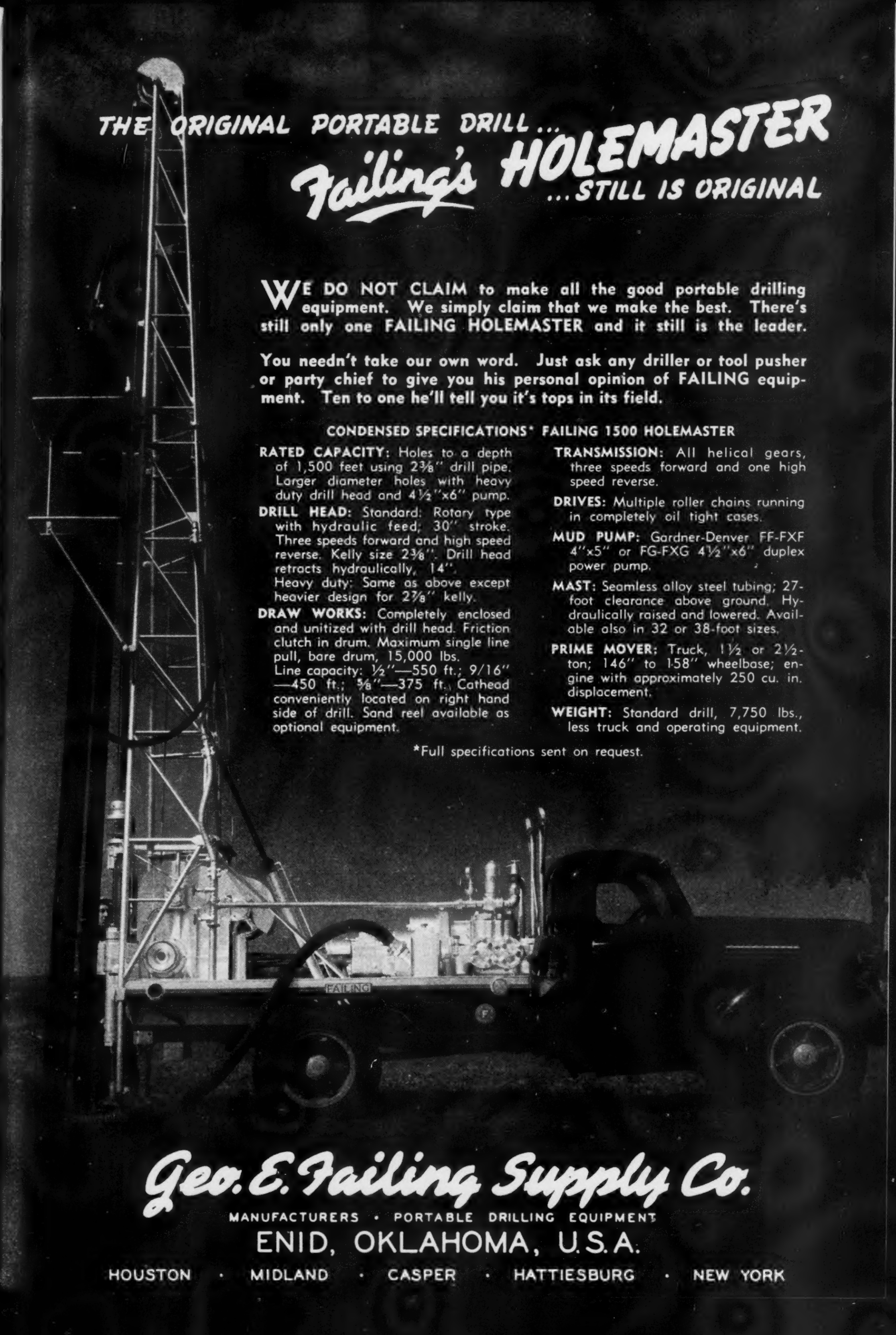
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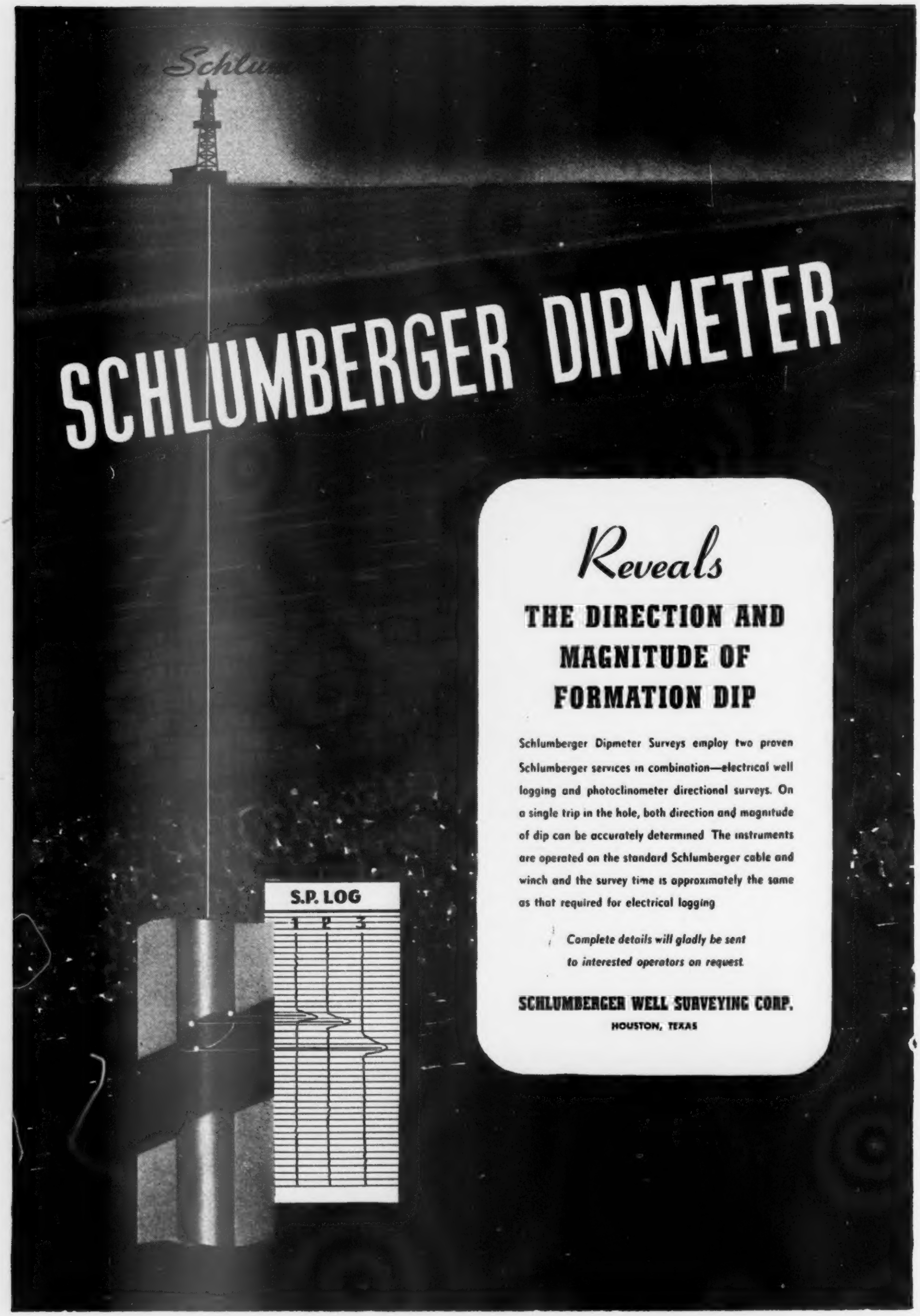

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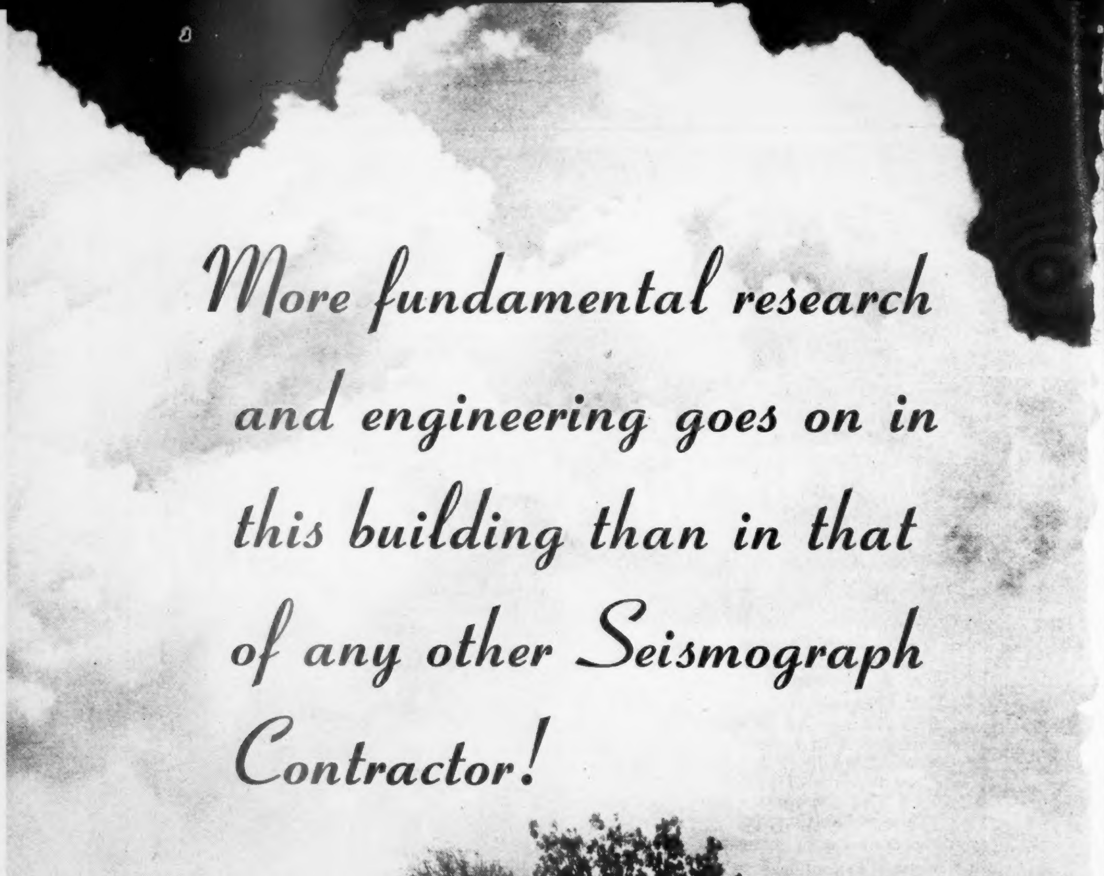

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APRIL, 1949

ALBERTA SYMPOSIUM*

LEA PARK AND BELLY RIVER FORMATIONS OF EAST-CENTRAL ALBERTA[1]

E. W. SHAW[2] AND S. R. L. HARDING[2]
Calgary, Alberta

ABSTRACT

Since the earliest geological investigations on the central Alberta Plains, the transition of Upper Cretaceous Montanan deposits from continental beds in the west to marine beds in the east has presented great difficulties in both surface and subsurface mapping. Accelerated petroleum exploration activity in the past 5 years has resulted in a large amount of new subsurface information on which to determine stratigraphical relationships. This paper describes and illustrates with one map and three cross sections, these relationships for the Lea Park and Belly River formations; the younger Bearpaw and Edmonton formations also enter into the discussions insofar as they are involved in the main subject.

The interfingering of the marine Lea Park formation with the predominantly non-marine Belly River formation makes possible the recognition of ten members which are somewhat arbitrarily placed in the latter formation. Each of these members has been described previously but most of them have been given more than one name because of uncertainties in correlation between localities. The present study, aided by a greater density of subsurface data, has, it is sincerely believed, succeeded in making sufficiently accurate correlations throughout east-central Alberta to justify discarding several local formation and member names. The correlations are based on lithologic, microfaunal, and electric-log data, although the cross-section illustrations include only the last criteria.

INTRODUCTION

Descriptions of the Lea Park and Belly River formations of east-central

* In the fall of 1945 at a meeting of the Alberta Society of Petroleum Geologists the members agreed to undertake the preparation of a symposium of papers on the stratigraphy of the Alberta basin. It was suggested that this should be on the order of a follow-up to the symposium on Alberta stratigraphy prepared by the Society and published by the Association in 1932. A symposium committee of four was appointed, composed of L. M. Clark, chairman, J. O. Galloway, J. O. G. Sanderson, and J. B. Webb. Later Mr. Galloway resigned and J. D. Weir was appointed in his place. In the course of time the Society approved proposals that the symposium include papers on Alberta oil fields as well as a paper on the front ranges of the Rockies in the vicinity of Banff.

The committee planned to have all the papers published in one Association-sponsored book. However, due to delays in the completion of some of the papers, it appears advisable to publish in the *Bulletin* those which have been completed and to attempt to secure the others for later publication.

ALBERTA SYMPOSIUM COMMITTEE

[1] Manuscript received, February 4, 1948.

[2] Geologist, Imperial Oil Limited.

Alberta have been included in a number of previous papers. The last of these by Nauss (4), published in 1945, is based on data available to the end of 1942. Since 1942, more than 150 core-test holes and more than 100 deep tests have been drilled in the area; hence, it is now possible to eliminate a number of previous problems and to establish a more regional correlation. The purpose of the present paper is to supplement previous reports rather than to deal comprehensively with the subject. The paleontology of the formations was included in Nauss' studies and will be published by him; it is therefore excluded from this paper.[3]

PREVIOUS WORK

The principal contributions to nomenclature, as correlated and compared with the classification proposed by the present writers, are shown in Table I.

DESCRIPTION OF FORMATIONS

The proposed classification of lithologic units is shown in Table II.

LEA PARK FORMATION

The Lea Park formation was named by Allan (1) in 1917 for a marine shale formation cropping out in the vicinity of Lea Park on the North Saskatchewan River.

The formation is a uniform series of gray, silty shales with local intercalations of sandy shale, ironstone concretionary bands, and bentonite. The formation underlies the entire area, varying in thickness from 450 to 810 feet. The thickness increases northeast as a result of successive lensing-out of several deltaic sand members of the Belly River formation in this direction and the inclusion of the silty marine shale off-shore facies of these sand members in the Lea Park formation. This relationship is illustrated in Figures 1, 2, 3, and 4. Within itself the Lea Park formation thickens slightly in the opposite direction as illustrated by the electric-log correlation lines *a* to *j* in Figures 2, 3, and 4. The formation was deposited in an epi-continental sea and the main source was from a distant borderland on the southwest.

The lower boundary of the formation is marked by the top of the "First White Speckled shale" zone of the Colorado marine shales. This is a consistent and reliable marker throughout the western plains of Canada and can be determined readily by either lithologic examination or electric-log correlation; it is used, therefore, as the datum in Figures 2, 3, and 4. The upper boundary of the Lea Park formation is gradational into the sands of the Belly River formation. The marine shale tongues which interfinger with the deltaic sands of the Belly River are being arbitrarily placed as members of that formation. Accordingly, the contact has a "stair-step" character as illustrated by Figures 2, 3, and 4.

Figure 2 shows the correlation of the Lea Park formation with the Milk River and Pakowki formations of the Southern Plains of Alberta.

[3] Shortly after this paper was prepared the following paper by A. W. Nauss appeared in the *Journal of Paleontology*, Vol. 21, No. 4 (July, 1947), pp. 329–43, "Cretaceous Microfossils of the Vermilion Area, Alberta." This paper contains essentially the material to which we made reference although in addition, Nauss' thesis contains a compilation of all the micropaleontology.

TABLE I
STRATIGRAPHIC SECTIONS OF VARIOUS WRITERS
AS CORRELATED BY PRESENT WRITERS

<table>
<tr><th>TYRRELL
(EAST CENT. ALBERTA)
1886</th><th colspan="2">ALLAN
(N. SASK. RIVER)
1917</th><th colspan="2">SLIPPER
(VIKING AREA)
1917</th><th colspan="2">NAUSS
(VERMILION AREA)
1945</th><th colspan="2">SHAW & HARDING
(EAST CENT. ALTA)
1947</th></tr>
<tr><td>PIERRE (INCLUDES BEARPAW, LEA PARK, GRIZZLY BEAR, & VANESTI)</td><td colspan="2">BEARPAW? FORMATION
?</td><td colspan="2">UPPER PIERRE SERIES</td><td colspan="2">BEARPAW FORMATION</td><td colspan="2">EDMONTON
BEARPAW</td></tr>
<tr><td rowspan="13">BELLY RIVER</td><td rowspan="11">BELLY RIVER SERIES</td><td>MYRTLE CREEK FORMATION</td><td rowspan="7">BELLY RIVER SERIES</td><td>PALE BEDS</td><td rowspan="9">BELLY RIVER GROUP</td><td>OLDMAN FORMATION</td><td rowspan="11">BELLY RIVER FORMATION</td><td rowspan="2">OLDMAN MEMBER</td></tr>
<tr><td rowspan="7">PAKAN FORMATION</td><td>VARIEGATED BEDS</td><td>PAKAN FORMATION</td></tr>
<tr><td rowspan="3">BIRCH LAKE SANDSTONE</td><td>UPPER BIRCH LAKE SANDSTONE</td><td>UPPER BIRCH LAKE MEMBER</td></tr>
<tr><td>MULGA TONGUE</td><td>MULGA MEMBER</td></tr>
<tr><td>LOWER BIRCH LAKE SANDSTONE</td><td>LOWER BIRCH LAKE MEMBER</td></tr>
<tr><td>GRIZZLY BEAR FORMATION</td><td>GRIZZLY BEAR TONGUE</td><td>GRIZZLY BEAR MEMBER</td></tr>
<tr><td>RIBSTONE CREEK FORMATION</td><td>UPPER RIBSTONE CREEK SANDSTONE</td><td>RIBSTONE CREEK MEMBER</td></tr>
<tr><td rowspan="5">LOWER PIERRE SERIES</td><td rowspan="6">LEA PARK FORMATION</td><td>VANESTI TONGUE</td><td>VANESTI MEMBER</td></tr>
<tr><td>VICTORIA SANDSTONE</td><td>LOWER RIBSTONE CREEK SANDSTONE</td><td>VICTORIA MEMBER</td></tr>
<tr><td>SHANDRO SHALES</td><td colspan="2" rowspan="3">LEA PARK SHALE</td><td>SHANDRO MEMBER</td></tr>
<tr><td>BROSSEAU FORMATION</td><td>BROSSEAU MEMBER</td></tr>
<tr><td>LOWER PIERRE</td><td>LEA PARK FORMATION</td><td colspan="2">LEA PARK FORMATION</td></tr>
<tr><td colspan="2"></td><td></td><td colspan="2">LLOYDMINSTER SHALE</td><td colspan="2">COLORADO GROUP</td></tr>
</table>

TABLE II

TABLE OF FORMATIONS

EPOCH		FORMATION	MEMBER	THICKNESS	ENVIRONMENT
UPPER CRETACEOUS	MONTANAN	EDMONTON / BEARPAW			MARINE-CONTINENTAL TRANSITION
		BELLY RIVER	OLDMAN	170' - 410'	CONTINENTAL (VALLEY - FLAT)
			UPPER BIRCH LAKE	0' - 50'	CONTINENTAL & MARINE (DELTAIC)
			MULGA	0' - 45'	MARINE (NERITIC)
			LOWER BIRCH LAKE	0' - 115'	CONTINENTAL & MARINE (DELTAIC)
			GRIZZLY BEAR	0' - 140'	MARINE (NERITIC)
			RIBSTONE CREEK	0' - 120'	CONTINENTAL & MARINE (DELTAIC)
			VANESTI	0' - 140'	MARINE (NERITIC)
			VICTORIA	0' - 95'	CONTINENTAL & MARINE (DELTAIC)
			SHANDRO	0' - 85'	MARINE (NERITIC)
			BROSSEAU	0' - 100'?	CONTINENTAL & MARINE (DELTAIC)
		LEA PARK		450'- 810'	MARINE (NERITIC)
	COLORADOAN				MARINE (NERITIC)

BELLY RIVER FORMATION

The term "Belly River" was originated by Dawson (3) for a series of predominantly continental deposits in the Southern Plains of Alberta, and Tyrrell (7) in 1886 applied the name to similar deposits in east-central Alberta. Later information and correlation have confirmed Tyrrell's application of the name in east-central Alberta. In the intervening years, however, the term "Belly River" has been raised to a group name in the type area where it consists of Russell's (5) Foremost and Oldman formations. In east-central Alberta, this subdivision can not be maintained and the term "Belly River" has to be used as a formation name. On the northeast in east-central Alberta, the formation becomes an interfingering succession of marine shales and deltaic sands; hence, it can be subdivided into a number of members as listed in Table II and illustrated by Figures 1, 2, 3, and 4. The formation underlies the greater part of the area; it thickens on the southwest as illustrated by Figures 3 and 4, indicating a source from highlands on the southwest.

The undivided formation consists of a series of gray to brownish gray to greenish gray, argillaceous, bentonitic sand closely interbedded with brownish gray to gray, carbonaceous shales and silts. Thin carbonaceous layers are characteristic of the normal facies. Thin coal seams characterize the continental to marine transition facies.

The environment of the typical Belly River beds appears to have been a peneplain between the highlands on the southwest and the epi-continental seas on the northeast. This peneplain was locally swampy and provided a suitable habitat for dinosaurs and other reptiles, the remains of which have been found in abundance, particularly on the Red Deer River south of east-central Alberta.

The lower boundary of the Belly River formation has been described in the description of the Lea Park formation. The Belly River is overlain by the marine Bearpaw formation or the continental Edmonton formation. Southeast of the area, the Bearpaw formation is typically a marine shale, but in the area itself it becomes progressively transitional northwestward into the overlying continental beds of the Edmonton formation. This transition becomes complete in the vicinity of the city of Edmonton where the main coal measures of the Edmonton formation were deposited in a coastal swamp environment contemporaneously with the basal beds of the marine Bearpaw formation and thus directly overlie the Belly River formation. Two hundred miles northwest, a series of continental beds essentially contemporaneous with the Belly River, Bearpaw, and Edmonton formations has been designated the Wapiti formation by Dawson (2).

Brosseau member.—The name "Brosseau" was introduced by Allan for sands exposed along the North Saskatchewan River valley between Shandro Ferry and Fort Island. Allan (1) describes the beds as follows: "The upper part of the formation consists of flaky sandstones and clayey sandstones. . . . The lower part of the formation consists of brown sandy shales, thin-bedded sandstone, and thin seams of coal." Elsewhere, from subsurface information, the member

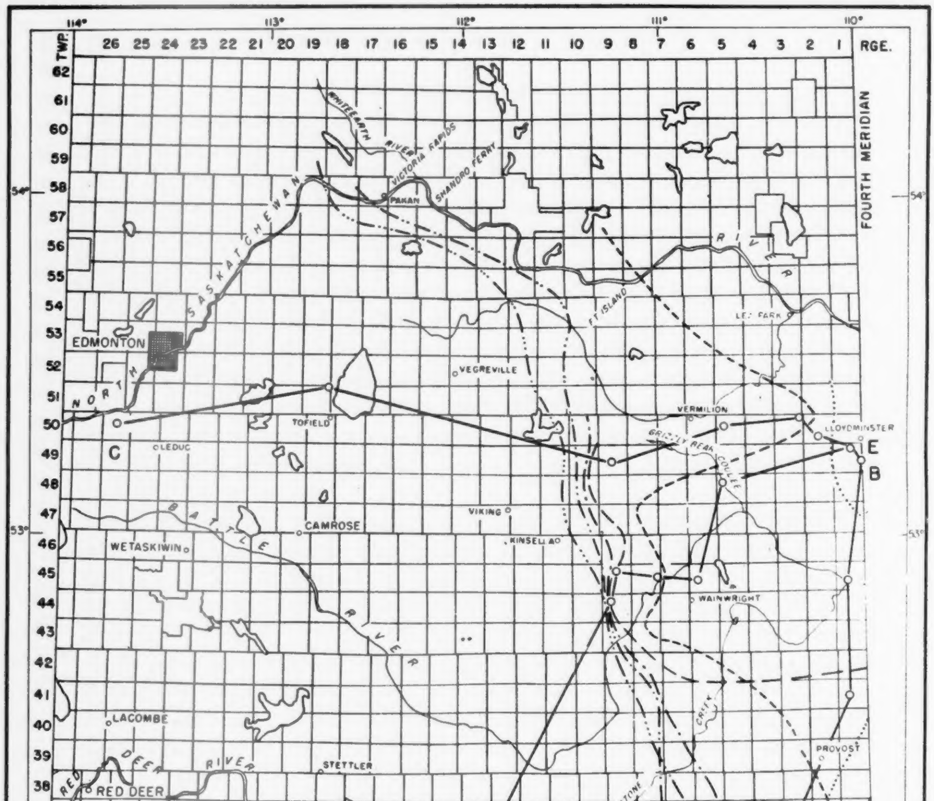
FIGURE I
INDEX MAP
EAST-CENTRAL ALBERTA
SHOWING
1) APPROXIMATE EASTERN EXTENT OF BELLY RIVER SAND MEMBERS
VICTORIA
BROSSEAU
2) APPROXIMATE WESTERN EXTENT OF BELLY RIVER SHALE MEMBERS
MULGA
GRIZZLY BEAR
VANESTI
SHANDRO
3) LINES OF CROSS SECTIONS
A—B FOR FIGURE 2
C—B FOR FIGURE 3
D—E FOR FIGURE 4
4) LOCATIONS OF DEEP TESTS USED IN CROSS SECTIONS
DEEP TEST
SCALE IN MILES
16 8 0 16 32 48 MI.
TWP.
RGE.
FOURTH MERIDIAN
ALBERTA
SASKATCHEWAN
EDMONTON
NORTH SASKATCHEWAN RIVER
WHITEEARTH RIVER
VICTORIA RAPIDS
SHANDRO FERRY
PAKAN
FT ISLAND
LEA PARK
VEGREVILLE
TOFIELD
LEDUC
VERMILION
LLOYDMINSTER
GRIZZLY BEAR COULEE
VIKING
CAMROSE
KINSELLA
WETASKIWIN
BATTLE RIVER
WAINWRIGHT
LACOMBE
RED DEER RIVER
RED DEER
STETTLER
PROVOST
RIBSTONE CREEK
YOUNGSTOWN
A
B
C
D
E

FIG. 1

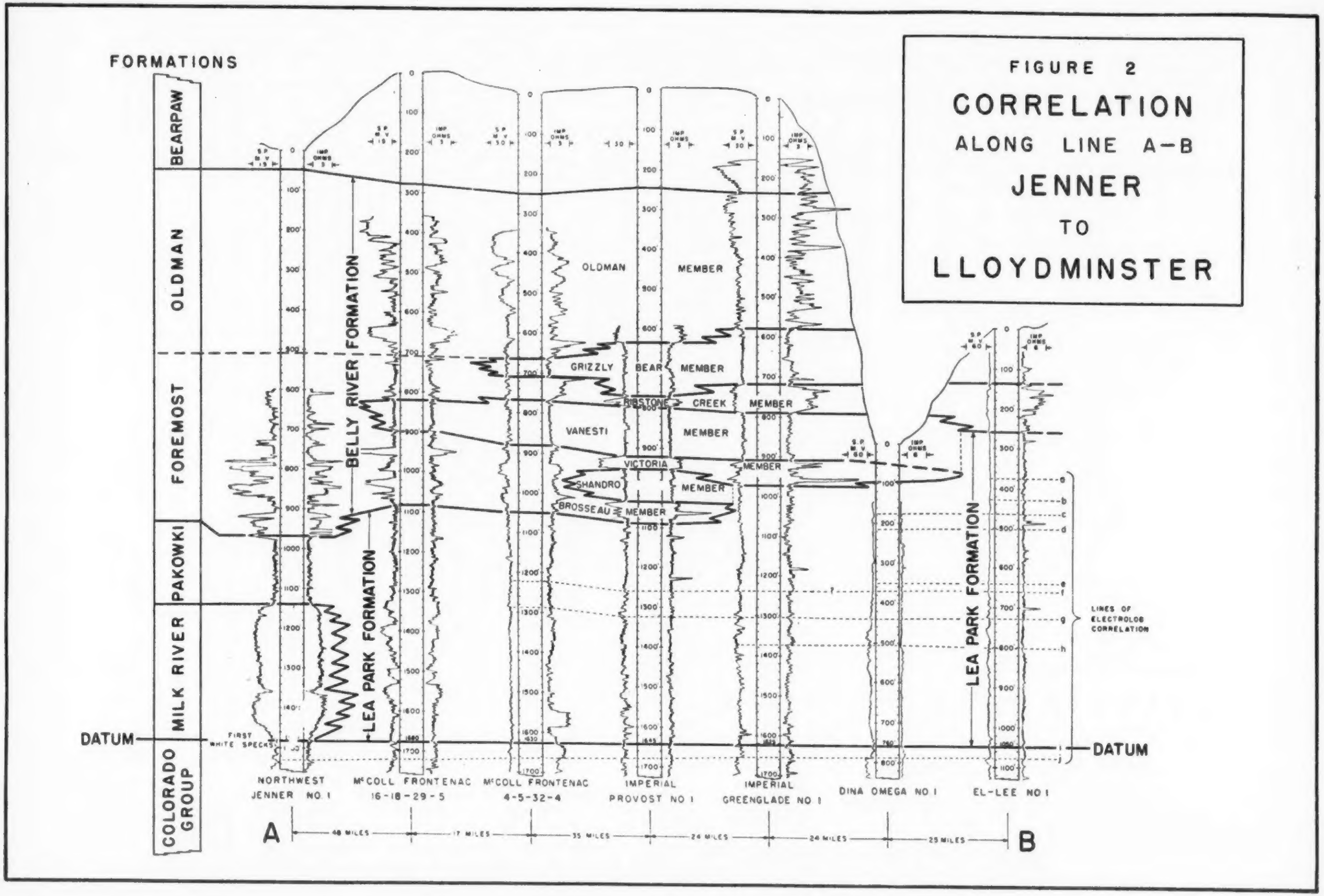
FIGURE 2
CORRELATION
ALONG LINE A–B
JENNER
TO
LLOYDMINSTER
FORMATIONS
BEARPAW
OLDMAN
FOREMOST
PAKOWKI
MILK RIVER
COLORADO GROUP
DATUM
BELLY RIVER FORMATION
LEA PARK FORMATION
OLDMAN MEMBER
GRIZZLY BEAR MEMBER
RIBSTONE CREEK MEMBER
VANESTI MEMBER
VICTORIA MEMBER
SHANDRO MEMBER
BROSSEAU MEMBER
FIRST WHITE SPECKS
LINES OF ELECTROLOG CORRELATION
NORTHWEST JENNER NO. 1
McCOLL FRONTENAC 16-18-29-5
McCOLL FRONTENAC 4-5-32-4
IMPERIAL PROVOST NO. 1
IMPERIAL GREENGLADE NO. 1
DINA OMEGA NO. 1
EL-LEE NO. 1
A
48 MILES
17 MILES
35 MILES
24 MILES
24 MILES
25 MILES
B

FIG. 2

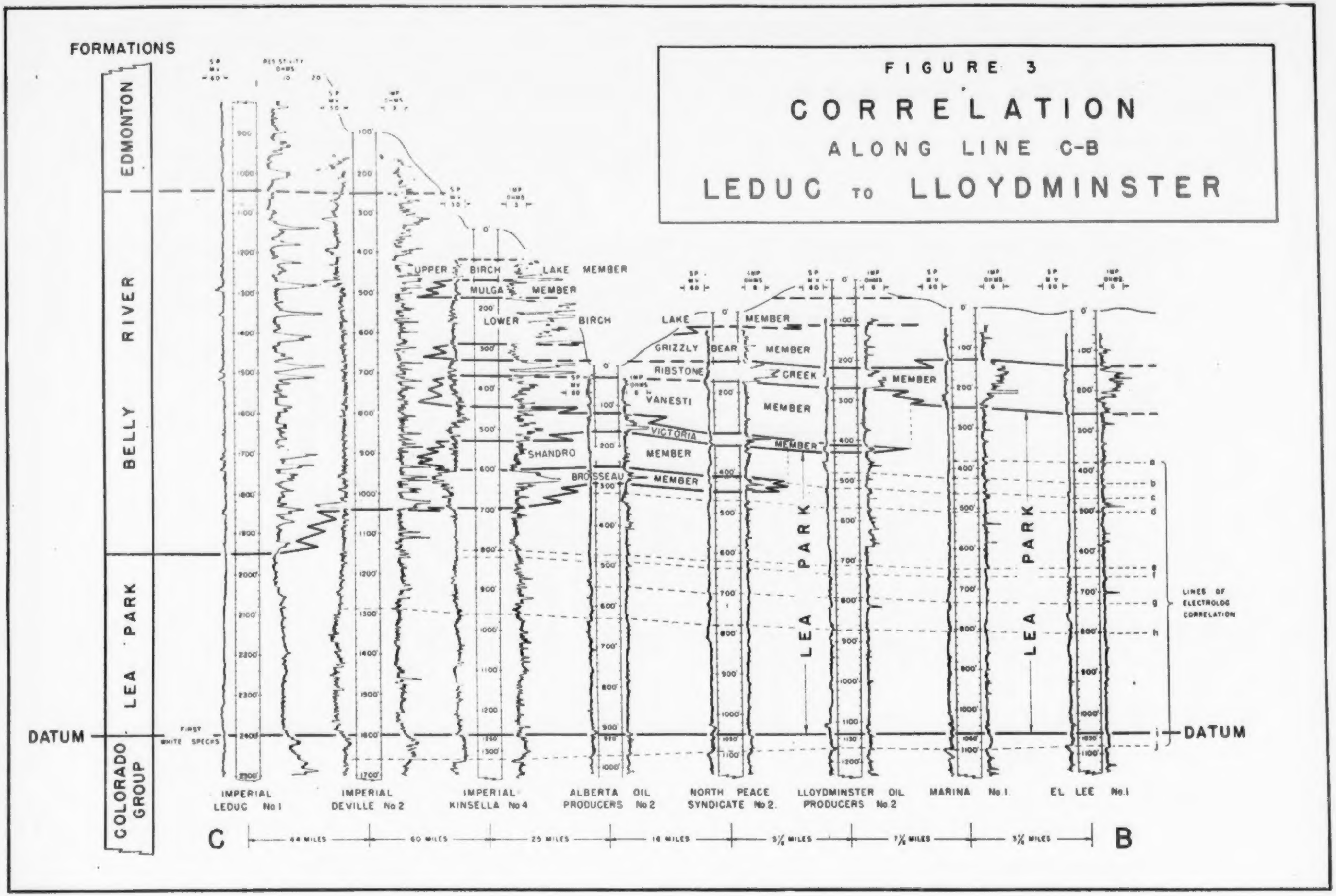
FIGURE 3
CORRELATION
ALONG LINE C-B
LEDUC TO LLOYDMINSTER
FORMATIONS
EDMONTON
BELLY RIVER
LEA PARK
COLORADO GROUP
DATUM
FIRST WHITE SPECKS
UPPER BIRCH LAKE MEMBER
MULGA MEMBER
LOWER BIRCH LAKE MEMBER
GRIZZLY BEAR MEMBER
RIBSTONE CREEK MEMBER
VANESTI MEMBER
VICTORIA MEMBER
SHANDRO MEMBER
BROSSEAU MEMBER
LEA PARK
LINES OF ELECTROLOG CORRELATION
IMPERIAL LEDUC No 1
IMPERIAL DEVILLE No 2
IMPERIAL KINSELLA No 4
ALBERTA OIL PRODUCERS No 2
NORTH PEACE SYNDICATE No 2.
LLOYDMINSTER OIL PRODUCERS No 2
MARINA No 1
EL LEE No 1
C
44 MILES
60 MILES
25 MILES
16 MILES
5½ MILES
7½ MILES
3½ MILES
B

Fig. 3

FIG. 3

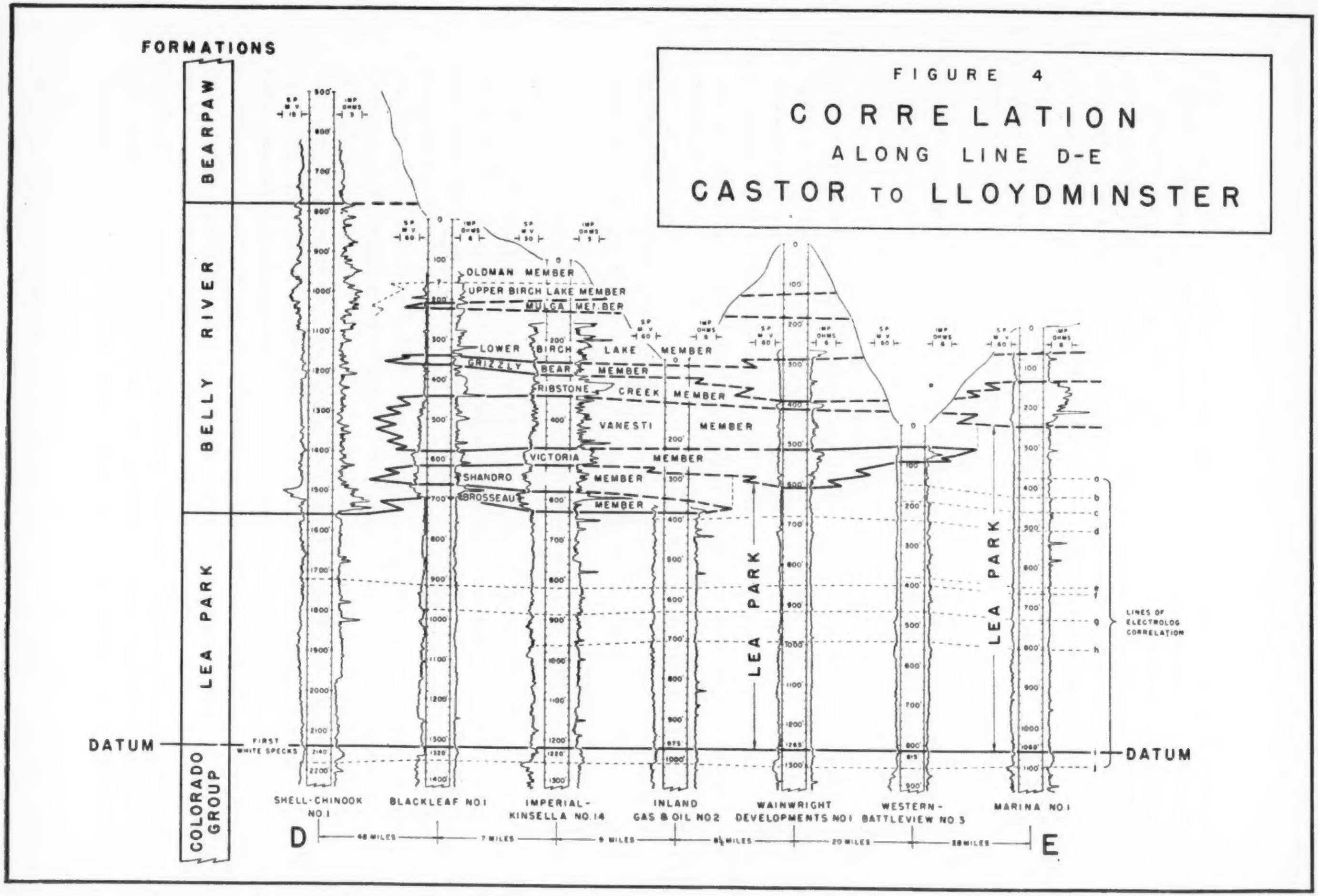
FIGURE 4
CORRELATION
ALONG LINE D-E
CASTOR TO LLOYDMINSTER
FORMATIONS
BEARPAW
BELLY RIVER
LEA PARK
COLORADO GROUP
DATUM
FIRST WHITE SPECKS
OLDMAN MEMBER
UPPER BIRCH LAKE MEMBER
MULGA MEMBER
LOWER BIRCH LAKE MEMBER
GRIZZLY BEAR MEMBER
RIBSTONE CREEK MEMBER
VANESTI MEMBER
VICTORIA MEMBER
SHANDRO MEMBER
BROSSEAU MEMBER
LEA PARK
LINES OF ELECTROLOG CORRELATION
SHELL-CHINOOK NO.1
BLACKLEAF NO.1
IMPERIAL-KINSELLA NO.14
INLAND GAS & OIL NO.2
WAINWRIGHT DEVELOPMENTS NO.1
WESTERN-BATTLEVIEW NO.3
MARINA NO.1
D
E
48 MILES
7 MILES
9 MILES
20 MILES
28 MILES

FIG. 4

consists of fine, gray calcareous sandstone and sandy, brownish gray shale. The depositional environment of the member was continental and marine deltaic.

Allan (1) and Slipper (6) considered the Brosseau formation as the equivalent of the Ribstone Creek formation cropping out near the mouth of Ribstone Creek and along the Battle River. Core-test and deep-test information show that the Brosseau beds are correlative with a deltaic sand which lies considerably below the Ribstone Creek formation. The sand is developed particularly well in the vicinity of the town of Provost. In keeping with the plan to designate as members each of the Belly River subdivisions in the northeast half of the area, it is proposed to reduce the Brosseau to member status.

On the basis of a great many subsurface data, the Brosseau member varies in thickness from almost nothing to 100 feet.

The present northeasterly extent of the member, insofar as it can be mapped by subsurface information, is shown in Figure 1.

Shandro member.—The name "Shandro" was applied by Allan (1) to exposures of " . . . dark gray marine shales containing calcareous and arenaceous concretions" exposed along the North Saskatchewan River below the mouth of White-earth River. Supplementary subsurface data indicate that the member also contains carbonaceous shales and brownish gray, silty shale with carbonaceous specks. The thickness varies from less than 1 to 85 feet. The environment of deposition was marine neritic.

In areal extent the member is indicated in Figure 1 as lying between the southwesterly limits of the Shandro member and the northeasterly limits of the Brosseau member.

Victoria member.—The name "Victoria" was introduced by Allan (1) for "massive beds of yellow sandstone" cropping out in the North Saskatchewan River valley 3 miles below Pakan. The exposure forms the Victoria rapids. Allan (1) and Slipper (6) considered the Victoria sandstone the equivalent of the Birch Lake sandstone on the southeast. Subsurface data now available indicate, however, that the Victoria lies considerably below the Birch Lake and is equivalent to the lower Ribstone Creek sandstone as described by Nauss (4). The name "Victoria" supersedes Nauss' name; therefore, it is proposed that the name lower Ribstone Creek be discarded.

An abundance of presently available subsurface information indicates that the lithologic character of this member varies from Allan's description to include fine- to medium-grained gray sandstone and brownish gray, carbonaceous, silty shale with local, thin coal seams. The thickness varies from almost nothing to 95 feet. The depositional environment was continental and marine deltaic. The present areal extent of the member is shown in Figure 1.

Vanesti member.—The "Vanesti" member was named by Nauss (4) for exposures along the Battle River valley near the mouth of Grizzly Bear Coulee. The member consists of gray shale, silty shale, clayey shale, and fine sand. Its thick-

ness varies from less than 1 to 140 feet. The depositional environment was marine neritic. The present areal extent of the member is shown in Figure 1.

Ribstone Creek member.—The name "Ribstone Creek" was applied by Slipper (6) to "greenish yellow, massive, soft sandstone at top; green and carbonaceous shale and coal, light grey sandstone at base," exposed principally near the mouth of Ribstone Creek. The colors described by Slipper are due to weathering. Fresh samples are, for the most part, gray in color. The thickness of the member varies from almost nothing to 120 feet. The depositional environment was continental and marine deltaic. Locally, both marine fossils and coal seams occur in the member. The member extends eastward far into the Province of Saskatchewan; it appears to be the most extensive of the Belly River deltaic deposits.

Grizzly Bear member.—The name "Grizzly Bear" was applied by Slipper (6) to the dark blue-gray, marine shale, containing ironstone and sandstone nodules with some beds of yellow incoherent sandstone, exposed principally on the lower part of Grizzly Bear Coulee. The member varies in thickness from less than 1 to 140 feet. The depositional environment was marine neritic. The present areal extent is shown in Figure 1.

Lower Birch Lake member.—The name "Birch Lake" was applied by Slipper (6) to "massive, cross-bedded sandstone, buff-coloured, containing lenses of harder sandstone" exposed on Birch Lake and in other near-by localities. Nauss (4) determined that a marine shale wedge entering from the northeast divided the beds into upper and lower members. The lower member consists predominantly of greenish gray to gray sands. The thickness varies from almost nothing to 115 feet. The depositional environment was continental and marine deltaic. The present areal extent of the member is fairly limited and can be deduced to some extent by reference to Figures 3 and 4.

Mulga member.—The name "Mulga" was applied by Nauss (4) to the gray shale with silt lenses and some carbonaceous material penetrated between the upper and lower Birch Lake members in four core-test holes south of Mannville. The type section is in Imperial Core Test No. 44 in Lsd. 13, Sec. 14, T. 49, R. 9, W. 4th Meridian. The present study has resulted in recognizing the member over a greater area. The thickness varies from less than 1 to 45 feet. The depositional environment was marine neritic. The present southwesterly extent of the member is shown in Figure 1.

Upper Birch Lake member.—The name "Upper Birch Lake" was applied by Nauss (4) to the upper part of Slipper's (6) Birch Lake sandstone. The member consists of gray to slightly yellow, medium-grained sand which weathers to a light rusty color. Thickness is from almost nothing to 50 feet. Depositional environment was continental and marine deltaic.

Oldman member.—The term "Oldman" was introduced by Russell (5) as a substitute for the term "Pale Beds" as applied to the upper division of Dawson's (3) Belly River series in Southern Alberta. Slipper (6) carried the term "Pale

Beds" to the central Alberta Plains; subsequently, Nauss (4), following Russell, substituted the term "Oldman" for the term "Pale Beds" in east-central Alberta. The term "Oldman" has formational status in Southern Alberta and Nauss gave it formational status in east-central Alberta. In keeping with their general plan, the present writers propose reducing it to member status in east-central Alberta. Moreover, the present writers propose that the Oldman member also include the Pakan beds of Allan (1) and Nauss (4) and the equivalent "Variegated beds" of Slipper (6). Subsurface geologists have been unable to differentiate between the "Pale" and "Variegated" beds in well samples. Accordingly, this subdivision is considered impractical even though perhaps technically justified. The Pakan beds (Variegated) undoubtedly represent a narrow transitional facies between the continental beds on the southwest and the marine and deltaic tongues which are developed on the northeast. Accordingly, the facies has a strong oblique attitude with respect to time levels. The Oldman member in reality represents the northeastward pinch-out of the typical continental Belly River facies; hence, the lithologic character and environment are similar to those described for the undivided Belly River formation.

CORRELATION METHODS

A fair understanding of Lea Park and Belly River relationships in the area was developed through the interpretation of the data obtained from an extensive core-drill program. This interpretation was greatly aided by the previous work of Nauss (4) in the Vermilion part of the area. To arrive at the more regional correlations shown in Figures 1, 2, 3, and 4, it was necessary to apply more local knowledge to the deep test records throughout the larger area. It was found possible to interpret and correlate the deep-test sections almost completely by electric logs. All available deep-test electric logs were used to confirm correlations and to map, to as great an extent as possible, in three dimensions. The top of the Colorado group provides the best electric-log marker throughout the area; hence, this marker was used as the datum. For each electric log, the datum was established first and correlation proceeded upward through the Lea Park formation without reference to higher features represented by the more variable Belly River beds. It was found that very slight electric-log features in the marine Lea Park could be traced for long distances; examples of such correlations are shown in Figures 2, 3, and 4. Confirmation of the main electric-log correlation characteristics was obtained by microfaunal zoning. In this connection it will be appreciated that the electric logs in the figures have lost much distinctive detail in reproduction. Once good correlation is effected through the Lea Park formation, the correlation of the various members of the Belly River formation becomes fairly obvious.

A few of the deep-test sections correlated in this manner have been included in the figures for illustration purposes. For the most part, a well within the area

can be correlated by the electric log if located with its proper reference to the section lines *AB*, *CB*, or *DE*, and Figure 1.

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VOL. 33, NO. 4 (APRIL, 1949), PP. 500-510, 4 FIGS.

OLDMAN AND FOREMOST FORMATIONS OF SOUTHERN ALBERTA[1]

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ABSTRACT

The Oldman and Foremost formations comprise an easily recognizable stratigraphic unit in Southern Alberta because of their lithologic character and position between marine strata. The Oldman is a continental type of deposit consisting essentially of light gray sandstones and gray shales. The Foremost formation underlies the Oldman conformably, and is brackish-water in origin. It is composed of sandstones, silts, shales of darker hues than those of the Oldman, and coal seams. These formations were laid down at or near the margins of the Bearpaw and Pakowki seas; hence, marine phases occur in the Foremost, and brackish-water phases in the Oldman. Thickness of the combined formations varies from 1,600 feet near the southwestern foothills to 600 feet in the eastern part of Alberta.

INTRODUCTION

The Oldman and Foremost formations occupy a prominent position in the stratigraphy of the Southern Alberta Plains as they constitute bedrock in approximately half of the area (Fig. 1). Consequently, they have received much attention in structural surveys and related studies. Both formations contain commercial coal seams, and this feature has also drawn attention to them. The Foremost formation has more carbonaceous beds, coal seams, fossil shell beds, and other beds that can be utilized in structural surveys than has the Oldman and as a result has received more detailed study in the field. Moreover, the coal and carbonaceous beds of the Oldman formation occur only at the top in most of the map area (Fig. 1); consequently, they have been eroded from most of the area, so that their outcrops are limited principally to the vicinity of the Oldman-Bearpaw contact. The remainder of the formation has very little to offer in the way of key horizons for structural surveys.

Published descriptions of these two formations are available, and the reader is referred to the bibliography at the end of this paper for detailed descriptions in specific areas. Since the publication of the latest of these reports and papers there have been surges of interest in oil exploration in Alberta and Saskatchewan, and a considerable quantity of new stratigraphical data has been accumulated. Some of this information has been won by more widespread studies of rock out-

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[2] Geologist, Research Council of Alberta.

Most of the information here presented has been obtained from the files of the California Standard Company. This company supplied field data and drilling records which form the basis of this paper. Drill-hole data have been furnished by the Alberta Petroleum and Natural Gas Conservation Board, the Imperial Oil Company, the McColl-Frontenac Oil Company, the Shell Oil Company of Canada, the Alliance Oils Ltd., and Pacific Petroleums. Facilities of the Research Council of Alberta have been used in the preparation of charts and maps. The writer wishes to thank these organizations for their help in making this contribution possible.

The writer has benefited by discussions with geologists of several oil companies and appreciates the ideas which have led to a better understanding of the stratigraphy of the Oldman and Foremost formations. Special mention should be made of J. D. Weir, California Standard Company, and E. W. Shaw, Imperial Oil Company.

crops; the remainder has come from examination of well logs. The electro-logging of deep drill holes, which has become a general practice in recent years, has yielded data which otherwise might not have been recorded. In this paper the writer has endeavored to bring this information up to date, with no more repetition than is necessary for the continuity of the theme.

The formations under consideration comprise a wedge of fresh- and brackish-water strata between marine strata, and thus form an important part of a cycle of sedimentation. The succession is as follows.

Upper Cretaceous
- Bearpaw formation—marine shale
- Oldman formation—continental deposits
- Foremost formation—brackish-water deposits
- Pakowki formation—marine shale

The Oldman formation has been known successively as the Pale and Yellow beds (2), Pale beds (3), and Oldman formation. In the Southern Alberta foothills, no distinction between the Oldman and Foremost has been recognized, and the two are collectively known as the Belly River formation. The Belly River may contain some strata older than the Foremost. In northern Montana the Oldman and Foremost formations together are known as the Judith River formation, and the Pakowki is called the Claggett formation (1). In Alberta the formations are exposed to advantage on the flanks of the Sweetgrass arch, which divides the map area into two unequal parts (Fig. 1).

DESCRIPTION OF FORMATIONS

Foremost formation.—Many excellent sections of this formation are exposed in the valleys of Milk, Bow, Oldman, and South Saskatchewan rivers and in the abandoned glacial run-off channels: Etzikom, Chin, and Forty Mile coulees. The strata of this formation exhibit the same characteristics wherever they are exposed. They are brackish-water in origin, and have minor intercalations of fresh-water and marine beds. Lithologic variations give the formation a distinctive, banded appearance, which is especially noticeable from a distance. Light gray sandstones, dark gray shales, black carbonaceous shales and coal seams, pale yellow silts, and rusty-colored concretionary bands form a variable succession. The beds vary in thickness from a fraction of an inch to many feet, and some persist laterally for several miles.

In many places, the formation is divisible on lithological grounds into members or zones. At the top there is generally a zone composed of coal seams and carbonaceous shales. This zone ranges from 80 to 220 feet in thickness, and is given such local names as Taber coal horizon, Grassy Lake lignite member, Bow Island coal member, and Redcliff coal zone. Below this is a zone composed of sandstones, shales, *Ostrea* and *Corbula* beds, with a few beds of carbonaceous shale. This zone is 100–150 feet thick. On the west flank of the Sweetgrass arch this is underlain by another coal zone approximately 30 feet thick. This lowest zone is called the McKay coal horizon and loses its identity eastward as it passes

into marine equivalents of the Pakowki formation. The McKay coal horizon is underlain by the basal Foremost sandstone locally called the Verdigris sandstone (4), from its occurrence in Verdigris Coulee near Milk River town.

The sandstones are commonly fine-grained, argillaceous, pale gray in color and poorly cemented, but in places indurated lenses and concretionary bands, which weather rusty brown, have developed in them. The thickness of an individual sandstone bed may be as great as 35 feet, and one such bed is prominent in Forty Mile Coulee and along the South Saskatchewan River north of Bow Island (Fig. 3, Section 1, base of section). The contacts between sandstone, shale, and carbonaceous beds are in some places sharp and in others gradational. There are many examples of contemporaneous erosion in the beds, where sandstone or shale rests on eroded coal or shale beds with the erosion contact clearly exposed.

The Foremost shales are variable in color and content, common types being greenish gray, gray with plant fragments, brown, gray, sandy, and carbonaceous. The coal seams and carbonaceous beds provide good horizons for structural mapping since they are conspicuous, and in many places extend several miles. Some idea of the thickness and number of these beds may be obtained by reference to Figure 3.

Fossil oyster shells occur either disseminated in sandstone or as beds ranging from a fraction of an inch to many feet in thickness. In some localities, they are persistent enough to act as key beds. Beds composed chiefly of shells of *Corbula* are common, ordinarily have a wide extent, and are relatively thin. They also are useful key beds. Bentonite beds are rare in most of the area and when present are commonly associated with coal or black carbonaceous shale.

Determination of the thickness of the Foremost formation offers some difficulty as there is interdigitation with the underlying Pakowki. Some brown marine shales in the lower part of the Foremost are identical with upper Pakowki beds, so that the contact is not everywhere obvious. The basal contact of the Foremost is placed at the base of the lowest prominent sandstone below the lowest carbonaceous bed, and overlies marine shales. Such sandstones are well developed in certain areas, and are shown to good advantage in the logs of the Shell's McWilliams 1, the Imperial's Lethbridge 1, and Ross Lake's Province 1 (Fig. 2). In some well logs where a basal sandstone is absent, the contact is placed at the base of the lowermost carbonaceous bed. The basal Foremost sandstones probably represent beach and deltaic sands of the slowly regressing Pakowki sea, and as such, do not form a continuous bed. Since the regression was eastward, the Foremost-Pakowki contact moves up-section in that direction and the basal sandstone member becomes younger. Comparison of the basal sandstones (Fig. 2, CD) in Ross Lake's Province 1 (2,430–2,480 feet) and the Imperial's Lethbridge 1 (1,240–1,258 feet) illustrates this point, as the basal sand in the latter is obviously the younger. Thickness of the basal sand varies from zero to 60 feet. Also, as toward the east the Foremost-Pakowki contact moves stratigraphically upward, the Pakowki thickens eastward at the expense of the Foremost.

The writer follows Russell(7) in placing the top of the formation at the top of the uppermost coal seam or carbonaceous bed, and at the break from dark- to light-colored sediments. This color change is not everywhere discernible in samples, and even at the outcrop in some places gives rise to arbitrary decisions. The Oldman-Foremost contact is placed at younger horizons eastward (Fig. 2), and lowermost Oldman beds in the western part of the area are equivalent in age to upper Foremost coal zones in the eastern part.

Oldman formation.—The greater part of this formation is fresh-water in origin, and the uppermost few feet alone show brackish-water characteristics in most of the area. It may be divided into two members, an upper coaly and carbonaceous member varying in thickness from a few feet to 80 feet or more and commonly referred to as the Lethbridge member, and a lower member, which consists essentially of sandstones and shales. These latter rocks occur in all gradations from sandy shale to argillaceous sandstone.

The sandstones are generally poorly cemented, and in many of them argillaceous material comprises the cement so that they weather readily to form a badland topography. Indurated sandstone lenses are common, and commonly weather brownish, and in many places are 15–20 feet thick. The sandstones are generally fine- to medium-grained, though coarse-grained types are not uncommon. The sandstone beds are so lenticular and variable in thickness that they can not be relied on as key beds in mapping geologic structure.

The shales are variable in color and texture. Gray, sandy shales predominate, and minor amounts of greenish shales, brown shales, shales with plant fragments, and reddish brown carbonaceous shales make up most of the balance. Thin beds of light-colored silt are not uncommon. Bentonite beds are rare, and have little lateral extent, excepting in the Lethbridge member.

The Oldman and Foremost bentonite beds more commonly occur in association with coal seams and beds of carbonaceous shale than with other types of shale and sandstone. The volcanic origin of most, if not all, bentonite presupposes a blanket deposition of ash. These bentonite beds owe their preservation to the quiet water of the coal-forming swamps into which the ash fell. Ash which fell into waters disturbed by currents was disseminated in mud and sand, and has produced bentonitic shales and sandstones.

Shells of fresh-water gastropods and pelecypods occur sporadically in the sandstones and shales, but are ordinarily poorly preserved. Shells of *Unio* are common fossils and denote a fresh-water origin for the enclosing rock. Here and there beds containing *Corbula*, *Ostrea*, and other brackish-water fossils are present in the upper part of the formation and signify oscillations in the shoreline of the near-by Bearpaw sea. Remains of vertebrates are common in some places, and this formation is world famous for its fossilized dinosaurian remains.

The upper, or Lethbridge, member thickens from northeast to west and southwest. On the east limb of the Sweetgrass arch in the vicinity of Schuler, its thickness varies from zero to 4 feet, and at Manyberries it is approximately 20 feet

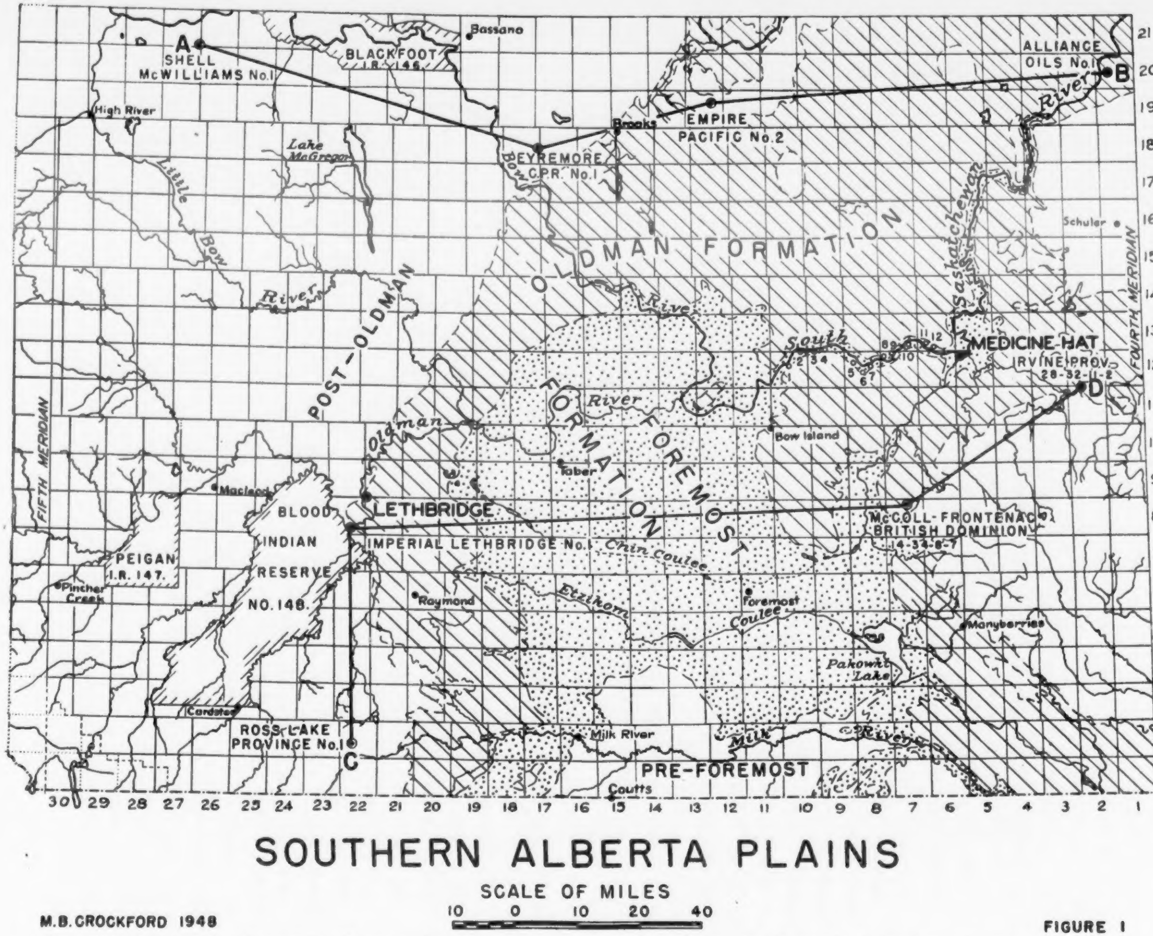

FIG. 1.—Index map showing extent of area under discussion, areas in which Oldman and Foremost formations are exposed in bedrock, location of cross sections AB and CD (Fig. 2), and location of measured stratigraphic sections 1–12 (Fig. 3).

thick (Fig. 1); on the west limb of the arch along Red Deer River northeast of Brooks, it is approximately 50 feet thick, and near Lethbridge 80 feet or more. This last is probably its maximum thickness. This member is rich in carbonaceous beds and coal seams, the latter increasing in thickness and economic importance westward to Lethbridge, where they are extensively mined. Wherever it is exposed, the member is a useful marker in structural mapping, but it has been eroded from most of the area. Ordinarily one or more bentonite beds are present close to the top of the member, and in southeastern Alberta near Manyberries a bed of white tuff as much as 3 feet thick is associated with the bentonite.

The Bearpaw-Oldman contact is ordinarily sharp and easy to identify. Basal Bearpaw beds in the form of dark brown shale, brown shale with sandstone pellets, or sandstone with marine fossils rest on coal seams or dark brown carbonaceous shales of the Lethbridge member. In a few places Bearpaw shales overlie typical Oldman sandstone, the Lethbridge member being absent. This feature, together with sandstone pellets in the basal shale suggest that the contact in places has the nature of a local unconformity. In the vicinity of Lethbridge the contact is not as easy to place, but it is usually drawn so as to include in the Oldman, beds of *Ostrea* shells that occur at the contact.

A general absence of transition beds at the top of the Oldman on the east limb of the Sweetgrass arch indicates that the Bearpaw sea advanced rapidly over that area. Thickening of the Lethbridge member westward and its beds of *Ostrea* shells on the west limb of the arch suggest that the advance of the sea became gradually slower in that direction. This feature is in marked contrast to the withdrawal of the Pakowki sea over the same area.

EXPLANATION OF FIGURES

Figure 1.—The areas of Oldman and Foremost outcrop are shown by hatching and stippling, respectively; blank areas are pre-Foremost formations in the vicinity of Milk River, and elsewhere are post-Oldman. The Oldman and Foremost formations are bedrock on the flanks of the Sweetgrass arch, a structure which has its apex in Montana and can be seen plunging northward into Alberta in the east central part of the map area. Development of the arch and the consequent comparatively rapid erosion along its axis are responsible for many of the good rock exposures in Southern Alberta.

Figure 2.—The eastward thinning of the Oldman formation is demonstrated in each of the cross sections *AB*, *CD*. Thinning of the Foremost is pronounced in the cross section *CD*, but the formation is fairly constant in thickness in the northern part of the area as shown in cross section *AB*. In the log of the Alliance Oils No. 1 the carbonaceous beds are distributed throughout the Oldman formation, and this character has also been observed in a few other places in surface outcrops in the eastern part of the plains of Southern Alberta. These carbonaceous beds are indicative of the change in facies from fresh-water to brackish-water which takes place in the Oldman formation. This change is more evident in

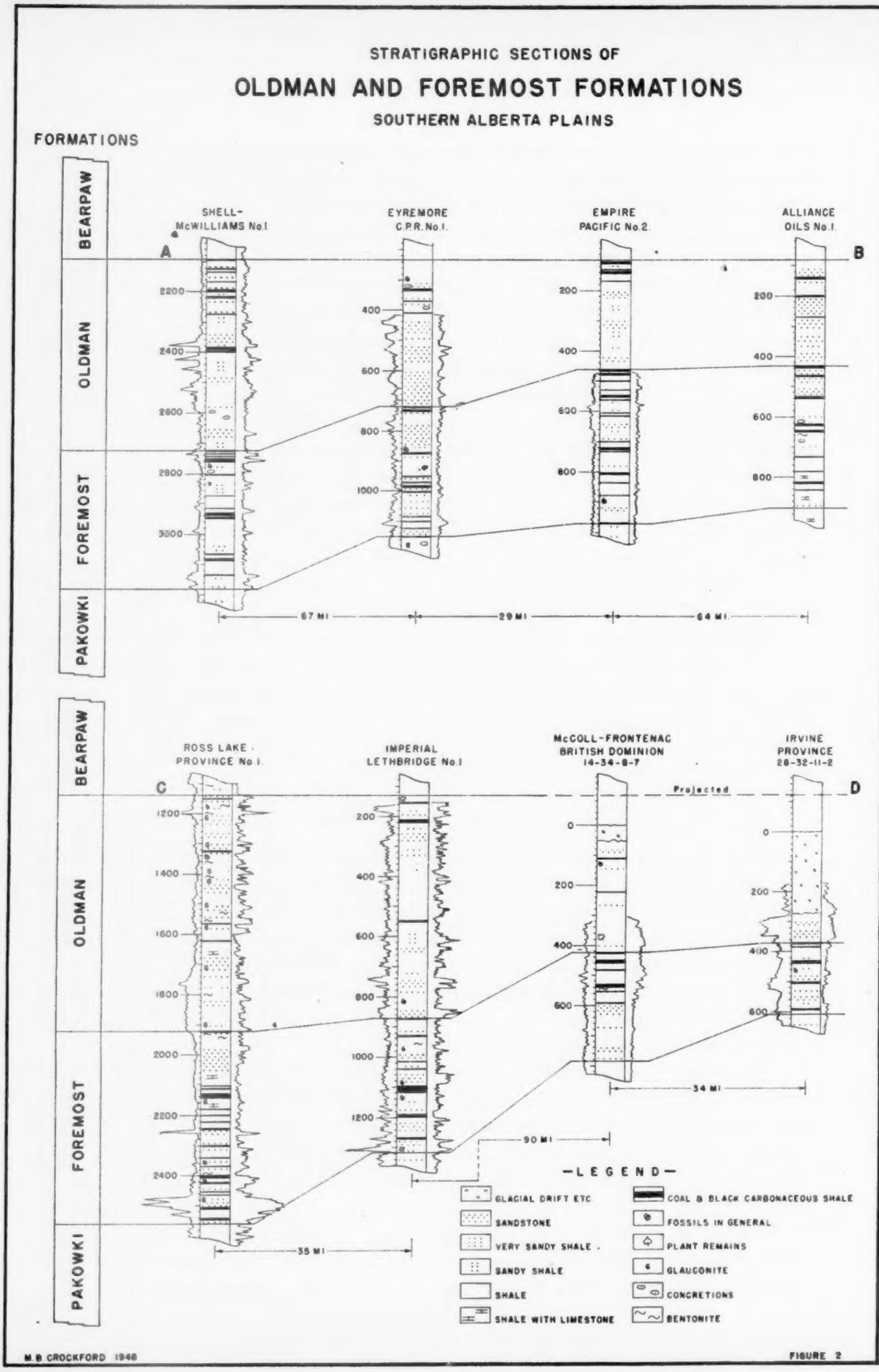

FIG. 2.—Stratigraphic sections AB and CD, showing formational contacts and lithologic characteristics in certain bore holes drilled in search of oil.

southwestern Saskatchewan where, though the formation preserves semblances of its lithological character, it contains brackish-water and marine fossils. In south-central Saskatchewan, the Oldman loses its identity completely, being replaced by marine shale.

The number and distribution of coal and carbonaceous beds in the Foremost formation varies from well to well. These beds are more or less evenly spaced in the formation, or may be bunched at the top or in the central part.

The comparatively sandy nature of the Oldman formation as compared with the Foremost is readily observed in both ditch sample and electrolog records, and in many wells the formational contact could be determined by inspection of the latter. However, well records of these two formations are very incomplete as a great many wells commence drilling in the Foremost; and consequently comparatively few holes have penetrated a complete thickness of this formation and fewer still of the Oldman.

Figure 3.—The stratigraphic sections pictured here were selected from over 250 which were measured in a structural survey along South Saskatchewan River between Bow Island and Medicine Hat. The linear distance between first and last sections is approximately 25 miles (Fig. 1). Correlations of marker beds were made in the field, and can not be shown in these few representative sections. The datum in the figure is a line arbitrarily chosen 150 feet above a certain prominent carbonaceous bed to which elevations of all other beds were referred in calculating elevations for structural contouring.

The diagram shows several features that are typical of the formations. One of these features is the varying stratigraphic position of the Oldman-Foremost contact. This contact is placed at the top of the uppermost prominent carbonaceous bed and at the place where the color change in sediments is most apparent. In many places, this color change is more noticeable from a distance than from close range. A comparison of the position of the contact in columnar sections 9 and 10 shows it to be more than 60 feet lower stratigraphically in the latter. The change in number and thickness of coal and carbonaceous beds is a characteristic of the Foremost formation. Lack of continuity of all beds is readily apparent, no one bed persisting for more than a few miles. A probable exception is the thick sandstone at the bottom of Section 1, which is correlated with a similar bed approximately 20 miles south in Forty Mile Coulee.

In columnar section 2 note the brackish-water fossil bed in the Oldman. This is a precursor of spreading brackish-water and marine conditions which prevailed in western Saskatchewan at this time.

Figure 4.—Isopachs in this figure are based on records for more than 30 drill holes and also on a few composite stratigraphic sections. Data are not wholly satisfactory since drill records of uppermost formations are incomplete. The combined formations show a rapid thinning from southwest to northeast, and a thickening again in the north. The northern thickening in these or equivalent strata is consistent with records of wells north of the area considered in this paper.

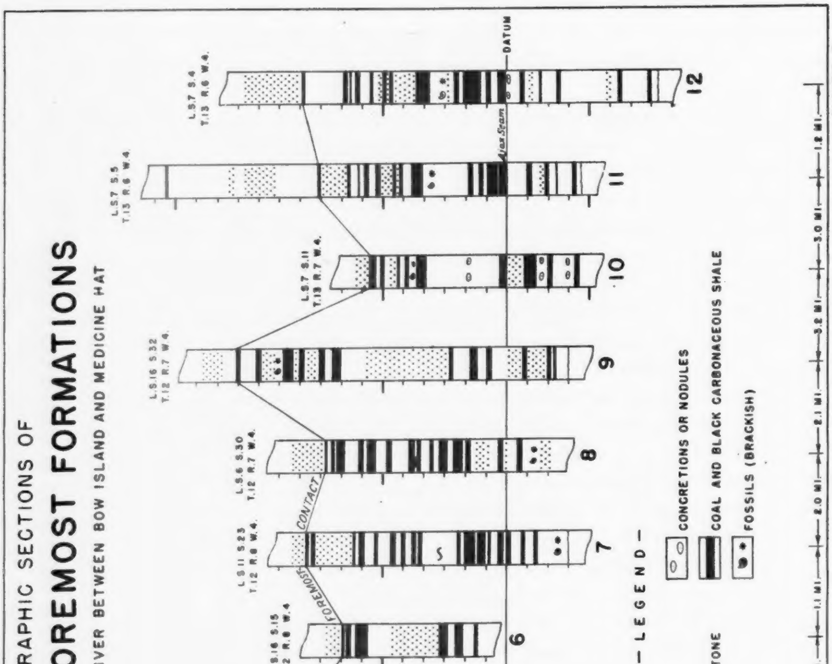

FIG. 3.—Measured stratigraphic sections of Oldman and Foremost beds cropping out in cutbanks along South Saskatchewan River between Bow Island and Medicine Hat.

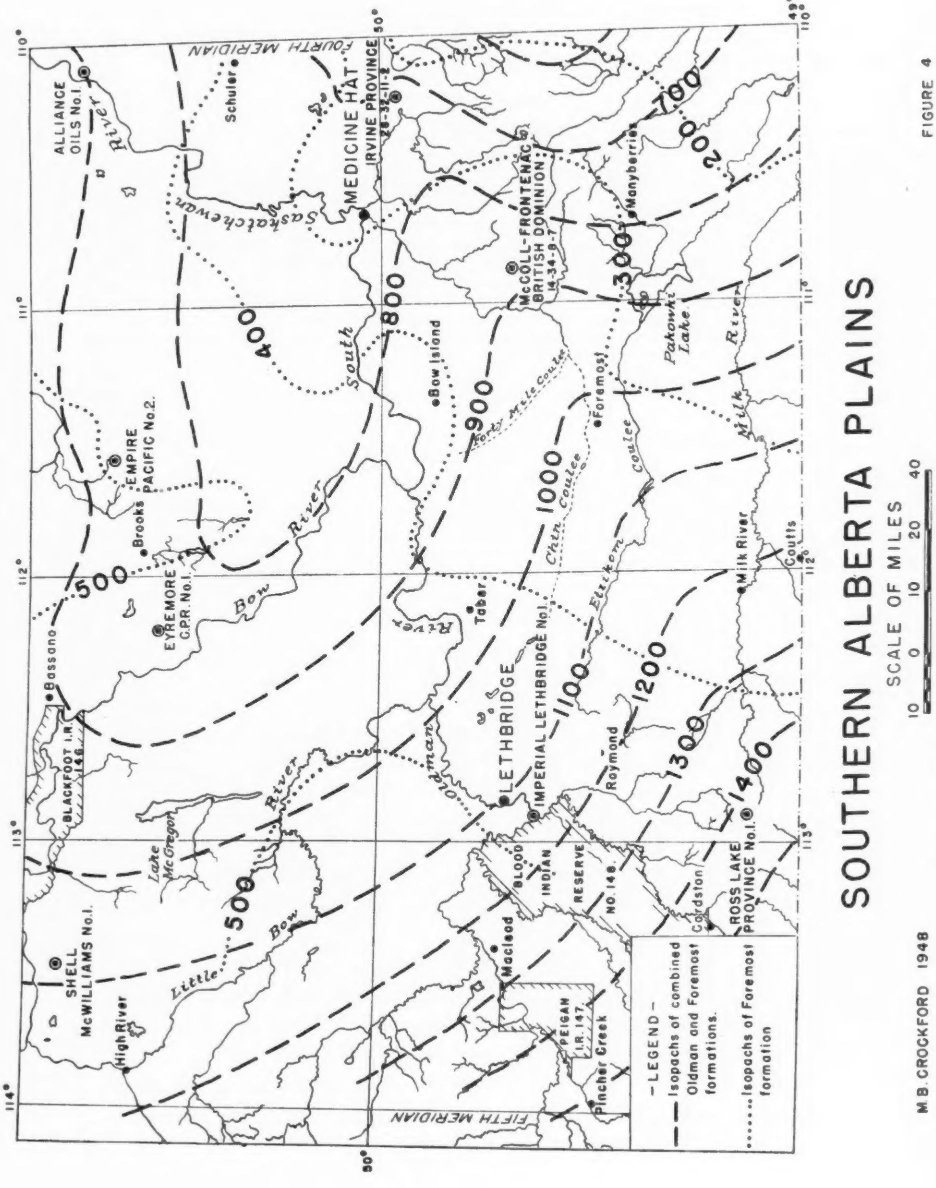

Fig. 4.—Isopachs of combined Oldman and Foremost formations and of Foremost formation.

The trend of isopachs of the Foremost formation is northeast-southwest, and at right angles to those of the combined formation. This trend indicates a southeastward withdrawal of the Pakowki sea.

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UPPER CRETACEOUS IN WESTERN PEACE RIVER PLAINS, ALBERTA[1]

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ABSTRACT

The territory covered includes approximately 3,600 square miles of Plains area in north-central Alberta. The area is approximately 500 miles northwest of Edmonton, and its western edge parallels the Alberta-British Columbia boundary. The strata described comprise nearly 3,000 feet in the west, to 2,000 feet in the east, of Upper Cretaceous formations including, in ascending order, the Dunvegan, Kaskapau, Cardium (Bad Heart), Wapiabi, and basal Member A of the Wapiti. Within the area, the name Smoky River is raised from formational to group rank and includes the Kaskapau, Cardium, and Wapiabi formations. A White Speckled Shale zone was observed in the Kaskapau and another in the Wapiabi. It is suggested that the term Cardium as a formational name be extended eastward onto the plains and that it embrace the Bad Heart sandstone along Smoky River. The term Chinook is applied to a littoral marine sandy shale and sandstone member in the upper part of the Wapiabi shales. Both *Ammonite* and *Inoceramus* fossil zones are listed and correlated from west to east. Formational thicknesses are compiled from isolated outcrops. The formations thin notably eastward, particularly in the Smoky River group.

Introduction

This paper describes the stratigraphy as revealed by outcrops of those Upper Cretaceous formations, ranging in age from the Dunvegan to basal Member A of the Wapiti formation, which occur in a part of the Peace River area of west-central Alberta. The region is bounded on the west by the Alberta-British Columbia boundary and extends eastward more than 80 miles to the 6th Meridian. It is bounded on the north generally by the Peace River and extends southward approximately 40 miles to Township 75 (Fig. 1). Although outcrops are none too plentiful, it was possible to trace several lithologic and fossil zones across almost the entire area.

Information has been obtained during the work of two seasons, the first during 1945 in the vicinity of the provincial boundary, and the second in 1946 in the remaining area eastward to the 6th Meridian. During 1946, the writer's colleague, J. Y. Smith, traversed the lower part of the Smoky River and established certain formation thicknesses, and lithologic and fossil zones.

The first part of the paper deals in particular with the lithologic characteristics of the formations; the second part lists the faunal horizons in various parts of the area.

Previous Work

Early Geological Survey of Canada reports containing some reference to the geology of the area include one by Selwyn (25) in 1875–76 and another by G. M. Dawson (6) in 1879–80. In numerous Geological Survey of Canada reports dating

[1] Manuscript received, April 4, 1948.

[2] Geologist, Imperial Oil Limited. The writer wishes to thank C. R. Stelck of Imperial Oil Limited and P. S. Warren of the University of Alberta, Edmonton, for their determinations of the fossils collected in 1945 and 1946, respectively. Thanks are extended to colleagues, particularly J. Y. Smith and G. R. Robertson, who have materially helped in collecting field data and in the preparation of this paper. The writer is indebted to E. W. Shaw and J. B. Webb for editing the manuscript.

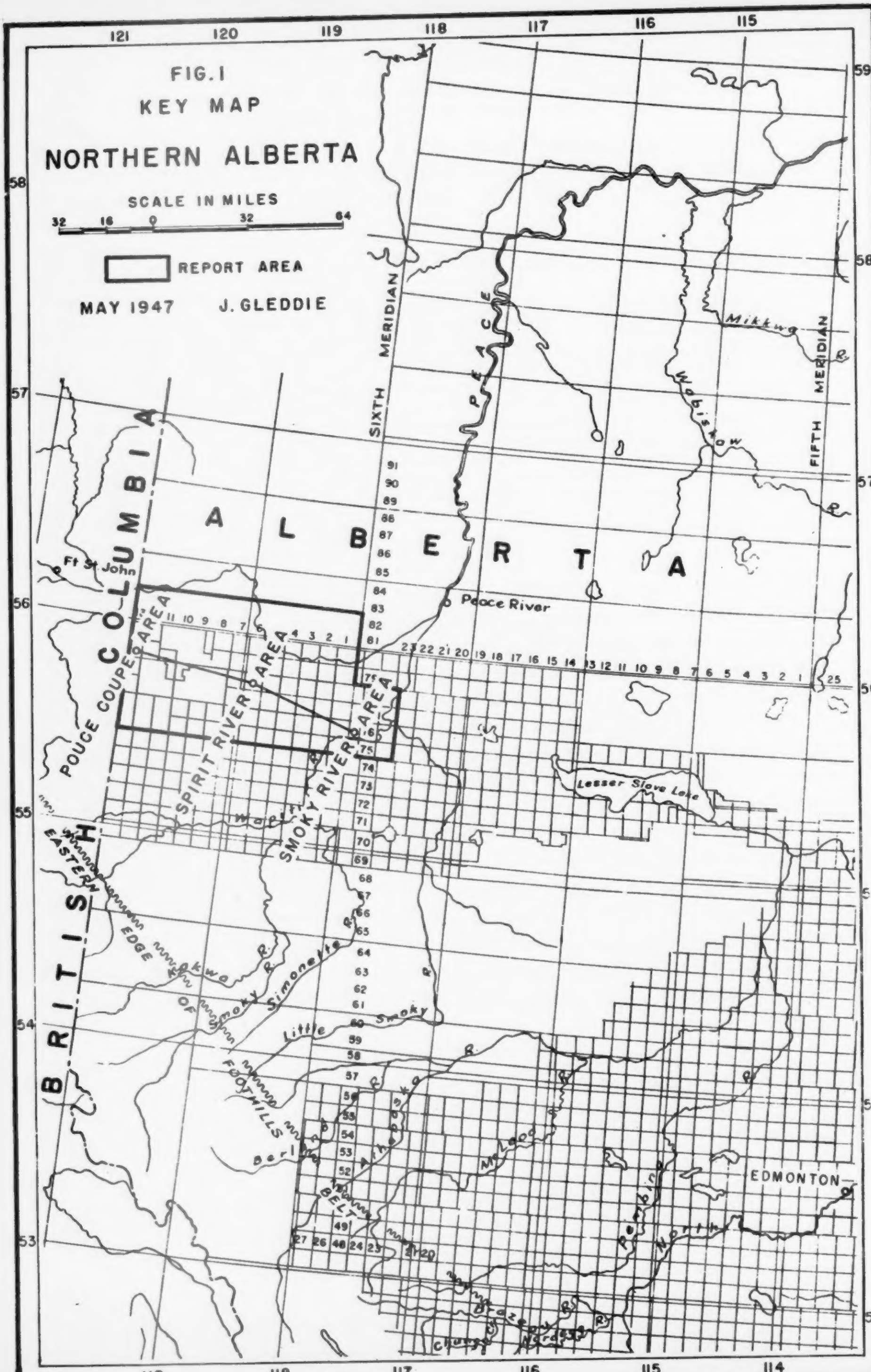


FIG. I
KEY MAP
NORTHERN ALBERTA
SCALE IN MILES
32 16 0 32 64
REPORT AREA
MAY 1947 J. GLEDDIE
ALBERTA
BRITISH COLUMBIA
SIXTH MERIDIAN
FIFTH MERIDIAN
PEACE
Peace River
Ft St. John
POUCE COUPE AREA
SPIRIT RIVER AREA
SMOKY RIVER AREA
Lesser Slave Lake
EASTERN EDGE OF FOOTHILLS BELT
EDMONTON
Wapiti
Smoky R.
Little Smoky
Simonette R.
Kakwa R.
Athabaska R.
McLeod R.
Pembina
North
Brazeau R.
Mikkwa R.
Wabiskaw

FIG. 1

from 1917 to 1945, McLearn (8 to 21) has established the succession of Upper Cretaceous rocks along the Peace and Smoky rivers. The eastern part of the area is included in the region mapped by Rutherford (24) in 1929 and by Russell (22) in 1931. On the west near Pouce Coupe, early investigations were conducted by Allan (1) in 1921 and by Allan and Cameron (2) in 1927. In 1929–30 Warren (27) and in 1940 Warren and Stelck (30) described important key fossil horizons in the Dunvegan formation and in the Smoky River group. In 1944, Crickmay (5) mapped the lower part of the Pouce Coupe River and a part of the Peace River east of the provincial boundary.

Description of Formations

A summary description of the formations is given in Table I. Figure 2 illustrates a correlation of the formations across the area from west to east.

DUNVEGAN FORMATION

The name "Dunvegan formation" was first used by G. M. Dawson (6) in 1880 for a group of fresh-water sandstones and shales at Dunvegan, an old trading center on the Peace River. The formation underlies practically the entire area and forms prominent escarpments along the canyon walls of the Peace River throughout more than 100 miles of its course from the provincial boundary to a point beyond the eastern edge of the area. In the west the formation is exposed up the Pouce Coupe River 18 miles, and in the central part uppermost beds of the formation were observed cropping out 5–7 miles upstream on Hamelin, Howard, Dunvegan and other creeks. Along the Smoky River the formation is prominently exposed for several miles downstream from Watino and along Racing Creek.

In general, the formation consists of fresh-water sandstones and shales with locally developed coaly beds and some brackish to marine phases. Sandy beds predominate in the lower and upper parts of the formation. Along parts of the main stream channels these sandstone beds form precipitous cliffs and extensive benches. The lithologic units themselves are lenticular and although the coarse sandstone phases are in many cases replaced in part by lenses of siltstone and shale, the zones have more or less lateral continuity because new lenses of similar sandstone normally reappear within them. The upper part of the formation is commonly marked by a white encrustation of salts which have been precipitated by seepage of alkaline water in the highest beds.

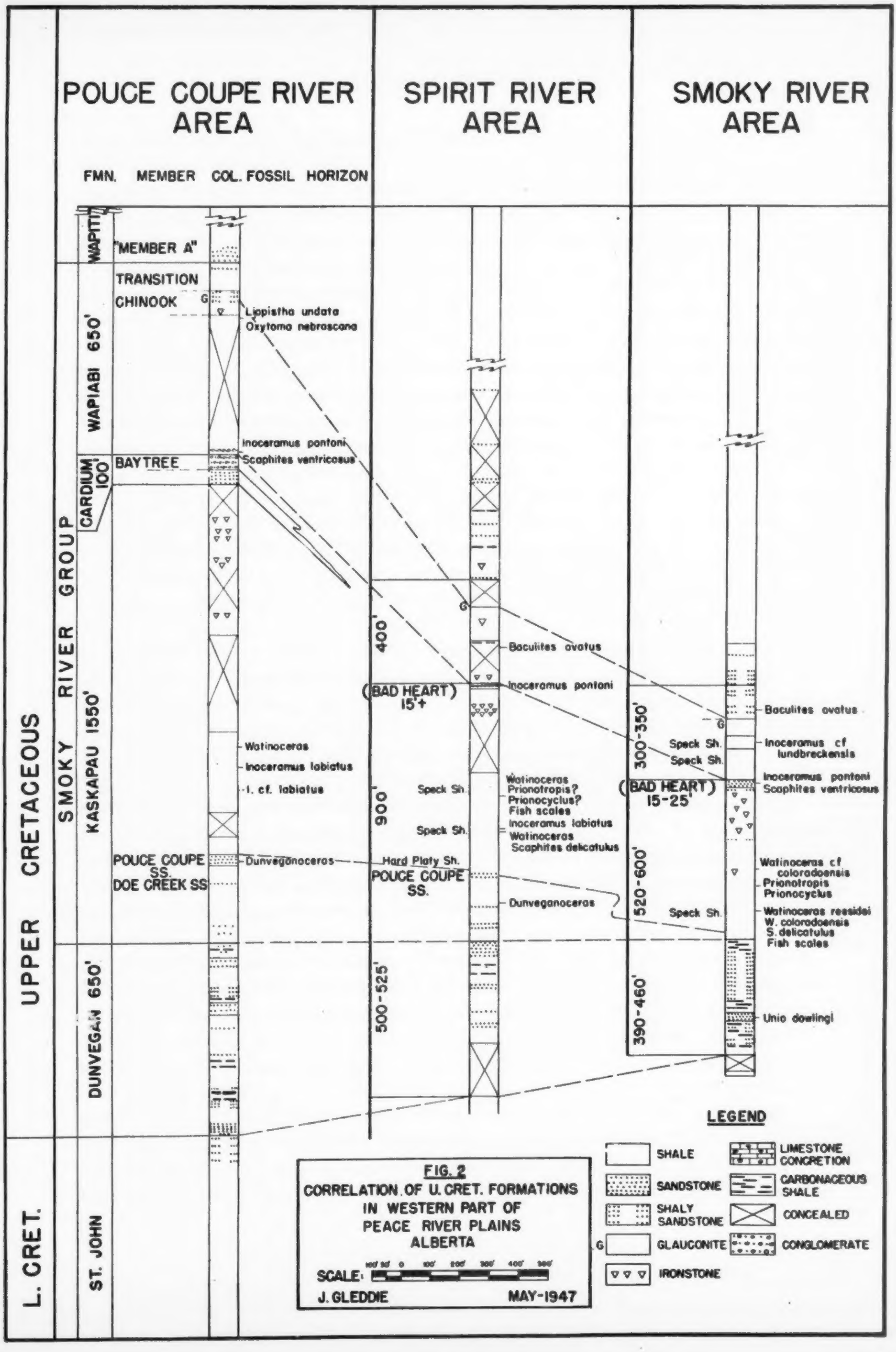
The formation overlies the marine St. John (Shaftesbury) formation and underlies the marine Kaskapau formation; both boundaries are transitional through zones 200–300 feet thick and of brackish-water origin. In this paper, these transition zones are arbitrarily placed in the adjacent formations, so that the Dunvegan contains chiefly fresh-water sediments. In the Pouce Coupe area, the contact with the underlying St. John (Shaftesbury) shales is drawn at the base of a massive, buff, coarse-grained sandstone which has a minimum thickness of 30 feet and which contains a *Unio* fauna. Along Peace River northeast of

TABLE I
TABLE OF UPPER CRETACEOUS SURFACE FORMATIONS
WESTERN PEACE RIVER PLAINS, ALBERTA.

<table>
<tr><th colspan="2">FORMATION</th><th colspan="2">MEMBER OR ZONE</th><th>LITHOLOGY</th><th colspan="3">THICKNESS IN FEET</th></tr>
<tr><td colspan="2">WAPITI</td><td colspan="2">MEMBER A</td><td>Sandstone, siltstone, shale, thin coal seams
Mainly Continental</td><td colspan="3">1100 - 1300</td></tr>
<tr><td rowspan="9">SMOKY RIVER GROUP</td><td rowspan="3">WAPIABI</td><td colspan="2">TRANSITION ZONE</td><td>Shale, Sandy Shale, Cone-in-Cone
Marine to brackish</td><td>Western Part</td><td>Central Part</td><td>Eastern Part</td></tr>
<tr><td colspan="2">CHINOOK MEMBER*</td><td>Shale, Sandy Shale, Ironstone, Glauconite
Marine</td><td rowspan="2">650</td><td rowspan="2">400</td><td rowspan="2">300-350</td></tr>
<tr><td colspan="2">*UPPER SPECKLED SHALE</td><td>Shale Marine</td></tr>
<tr><td rowspan="2">CARDIUM (BAD HEART OF EASTERN AREA)</td><td colspan="2">*BAYTREE MEMBER</td><td>Chert and Quartzite conglomerate
Marine</td><td rowspan="2">100</td><td rowspan="2">15</td><td rowspan="2">15-25</td></tr>
<tr><td colspan="2"></td><td>Sandstone</td></tr>
<tr><td rowspan="4">KASKAPAU</td><td colspan="2">*LOWER SPECKLED SHALE</td><td>Shale Marine</td><td rowspan="4">1550</td><td rowspan="4">900</td><td rowspan="4">520-600</td></tr>
<tr><td rowspan="3">TRANSITION ZONE</td><td>*POUCE COUPE MEMBER</td><td>Sandstone
Shale Marine</td></tr>
<tr><td>*DOE CREEK MEMBER</td><td>Sandstone and</td></tr>
<tr><td></td><td>Shale, siltstone, sandstone brackish</td></tr>
<tr><td colspan="2">DUNVEGAN</td><td colspan="2"></td><td>Sandstone, shale, siltstone, thin coal seams
Continental and brackish</td><td>650</td><td>500-525</td><td>390-460</td></tr>
</table>

* These members and zones are not known to occur throughout the entire area

TABLE I



POUCE COUPE RIVER AREA
SPIRIT RIVER AREA
SMOKY RIVER AREA
FMN. MEMBER COL. FOSSIL HORIZON
UPPER CRETACEOUS
L. CRET.
SMOKY RIVER GROUP
WAPITI
"MEMBER A"
TRANSITION
CHINOOK
WAPIABI 650'
Liopistha undata
Oxytoma nebrascana
CARDIUM 100'
BAYTREE
Inoceramus pontoni
Scaphites ventricosus
KASKAPAU 1550'
Watinoceras
Inoceramus labiatus
I. cf. labiatus
POUCE COUPE SS.
DOE CREEK SS
Dunveganoceras
DUNVEGAN 650'
ST. JOHN
400'
(BAD HEART) 15'+
Baculites ovatus
Inoceramus pontoni
900'
Speck Sh.
Watinoceras
Prionotropis?
Prionocyclus?
Fish scales
Inoceramus labiatus
Watinoceras
Scaphites delicatulus
Hard Platy Sh.
POUCE COUPE SS.
Dunveganoceras
500-525'
300-350'
Baculites ovatus
Inoceramus cf lundbreckensis
(BAD HEART) 15-25'
Inoceramus pontoni
Scaphites ventricosus
520-600'
Watinoceras cf coloradoensis
Prionotropis
Prionocyclus
Watinoceras reesidei
W. coloradoensis
S. delicatulus
Fish scales
390-460'
Unio dowlingi
LEGEND
SHALE
SANDSTONE
SHALY SANDSTONE
GLAUCONITE
IRONSTONE
LIMESTONE CONCRETION
CARBONACEOUS SHALE
CONCEALED
CONGLOMERATE
FIG. 2
CORRELATION OF U. CRET. FORMATIONS IN WESTERN PART OF PEACE RIVER PLAINS ALBERTA
SCALE: 100' 50' 0 100' 200' 300' 400' 500'
J. GLEDDIE
MAY-1947

FIG. 2

Spirit River town, the lower contact lies below river level. On Smoky River near Racing Creek, J. Y. Smith[3] has arbitrarily drawn the base of the Dunvegan formation where the shales become silty and somewhat carbonaceous. In the Pouce Coupe area, the contact with the overlying Kaskapau formation is drawn at the base of a 20-foot fissile shale bed containing many bands of thin ironstone and a few beds of sandstone approximately 6 inches thick. This is in turn underlain directly by an 18-foot bed of coarse sandstone, somewhat shaly in places, followed by a 1-foot dark shale bed containing thin coal seams. Along the Peace River at Dunvegan ferry in the central part of the area, the upper contact is sharply defined. It is placed at the top of a sandy member varying in thickness from 30 to 50 feet and changing in lithological character from a coarse-grained, massive buff-weathering sandstone to white-weathering siltstone within a lateral distance of 500 feet. The overlying Kaskapau beds consist predominantly of shale and silty shale containing ironstone throughout a zone at least 38 feet thick. Along the Smoky River at Watino in the eastern part of the area, the uppermost contact is drawn at the top of a 3-inch coal seam which overlies the highest massive medium-grained gray-weathering sandstone. Along Racing Creek 7½ miles northeast of Watino, the contact is similar excepting that the coal seam is absent and the fissile and silty shales of the overlying Kaskapau rest directly on uppermost Dunvegan sandstone.

In the west, along Pouce Coupe River and Peace River, a total thickness of 650 feet was measured. A similar thickness was encountered in drilling the Alaska Highway Oil and Gas well No. 3 (Lsd. 2, Sec. 9, T. 80, R. 3, W. 6th) which is in the valley of the Pouce Coupe River. The Dunvegan-Kaskapau contact is exposed at ground level near the well site and the base of the formation was encountered at the depth of 650 feet. The lithologic description indicated in Figure 5 is from a log of the well by the Petroleum and Natural Gas Conservation Board, Calgary, Alberta, and includes certain modifications of formation contacts made by the writer. Along Peace River north of Spirit River town the total thickness is thought to be between 500 and 525 feet. Only the uppermost 340 feet are exposed along the canyon walls and it is estimated that an additional thickness of as much as 185 feet may extend below the level of the river. Farther east along Racing Creek and Smoky River, Smith and the writer measured a thickness ranging from 390 to 460 feet. Rutherford (24) reports a thickness of 400 feet at the town of Peace River. In the foothills on the west, Wickenden and Shaw (32) report a thickness ranging from 800 to 1,200 feet.

According to McLearn (21) the formation is known to extend south of the Wapiti River.

Regarding the age of the Dunvegan formation, McLearn (21) states that, "All students of Canadian Cretaceous fauna today accept an early Upper Cretaceous age for the Dunvegan formation, and, tentatively at least, a Cenomanian date in terms of European chronology." In the same report he has indicated

[3]Personal communication.

several guide fossils including the non-marine *Unio dowlingi* fauna and the marine *Inoceramus dunveganensis* fauna. Strata observed by the writer to contain the marine pelecypod *Brachydontes multilinigera* has in this paper been included in the overlying Kaskapau formation. In the Pouce Coupe area this species occurs approximately 120 feet above the top of the formation whereas along the creeks north of Spirit River approximately 50 miles east, it occurs precisely at the top. It was not observed along the Smoky River still farther east. In the Pine River area of the foothills on the west, the flora of the Dunvegan as determined by Bell has been discussed by Williams and Bocock (33, p. 219) who state that "The Dunvegan flora appears to be definitely younger than the upper Blairmore flora. . . . " According to C. R. Stelck[4] the uppermost Blairmore flora coincides with the lowest flora found in the Dunvegan. In this paper, the beds containing the *Dunveganoceras* fauna (Warren and Stelck, 30) are included in the basal part of the overlying Kaskapau shales.

SMOKY RIVER GROUP

The name "Smoky River" was first applied by G. M. Dawson in 1879 (6, p. 115B) for the "Upper dark shales" exposed on Smoky River. In 1918, McLearn (10, p. 2C) subdivided the Smoky River formation into three members, namely the "Lower shale," "Bad Heart sandstone," and "Upper shale," and on the basis of fossil remains, the lower two members were grouped together. In 1926, McLearn (15, p. 117) assigned the name "Kaskapau" to the Lower shale member. McLearn and Henderson (18) have proposed the shortening of the name Smoky River to Smoky.

The writer proposes that where applicable the name Smoky River be raised to group rank to include in ascending order the Kaskapau, Cardium, and Wapiabi formations.

KASKAPAU FORMATION

The shales of this formation underlie almost the entire area of this report and constitute the bedrock throughout most of its northern half. This region is generally known as the plains area and extends from the Peace River on the north to the Cardium escarpment on the south.

Although practically the entire upper third of the formation is concealed in the vicinity of Pouce Coupe and Spirit River, it is inferred from several outcrops occurring at widely separated points that the formation consists predominantly of marine shales. The basal transitionary zone, consisting of brackish to marine shale, silty shales, and sandstone, is included in the formation. This transition zone includes the Doe Creek and Pouce Coupe sandstone members (Warren and Stelck, 30). Near Pouce Coupe the zone is 300 feet thick, at Spirit River 230 feet thick, and on the Smoky River it is probably less than 75 feet thick. A White Speckled Shale zone, probably corresponding with the Second Speckled Shale zone of the Colorado shales of Southern Alberta Plains area, was observed north of

[4] Personal communication.

FIGURE 5

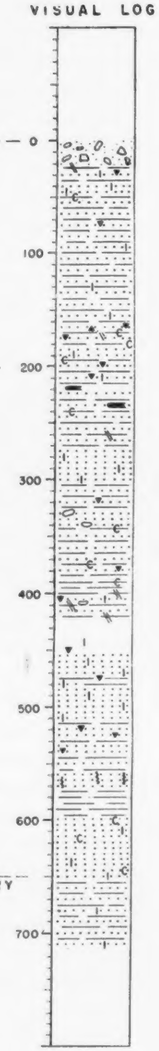
DUNVEGAN FORMATION 650 FEET

(UPPER CRETACEOUS)

ALASKA HIGHWAY NO.3

(LSD. 2, SEC.9, TP.80, RGE.13, W.6)

VISUAL LOG



* KASKAPAU
DUNVEGAN

DUNVEGAN
SHAFTESBURY

	DESCRIPTION
0 - 20	Glacial drift
20 - 30	Sh., gy., sdy. bentonitic; Ss., limy; Fe-stone; Coaly stks.
30 - 60	Ss., light gy., med & f. grd., limy, s & p; traces carb. Sh.
60 - 80	Ss., gy. Sh., sdy; Fe-stone
80 - 160	Ss., very f to f grd., mic., limy; Sh. pyritic, plant remains; Fe-stone
160 - 170	Sh. gy. carb.; Ss., gy; Fe-stone; trace Glauc.
170 - 180	Ss., very f. to f. grd.; Sh., gy., bentonitic, carb.; Fe-stone
180 - 190	Ss. very f. to f. grd., limy.
190 - 210	Sh., gy., trace carb., Sdy; Ss., very f. to f. grd., limy; Fe-stone
210 - 230	Ss., limy, very f. to f. grd.; Sh., sdy. carb., gy.; Fe-stone.
230 - 240	Ss., f. grd; Sh., gy., carb.; trace Coal.
240 - 270	Ss. very f. grd., mic. gritty; Sh., bentonitic
270 - 300	Ss., gy., buff, med. to f. grd., limy.
300 - 380	Ss Sh, gn., carb.; Fe-stone; Chert pble. 330, 340.
380 - 400	Sh., gy., gn., bentonitic, trace carb.
400 - 410	Ss., f. grd., limy; Sh., gr., gn., buff, bentonitic; Fe-stone; Chert; blk. chert pbles.
410 - 420?	Sh., bent. sdy. Ss.
420 - 440	Missing
440 - 450	(1 inch Core) Ss., gy. argil., very f. grd.; plant remains; calc. min
450 - 460	Fe-stone; Ss., f. grd.
460 - 470	(Core) Ss., gy., f. grd., lsly. consol., limy, s. & p.
470 - 480	Ss., f. grd., s. & p. gy., shly.; Sh., Fe-stone.
480 - 510	Ss., gy., buff., f. grd., limy, s & p.
510 - 520	Ss., Sh., gy.; Fe-stone
520 - 540	Ss., gy., med. grd., limy; Sh. gy.; Fe-stone; Carb. spks.
540 - 550	Sh. gy.; Ss., very f. to f. grd., mic.; Fe-stone
550 - 560	Sh.; Ss., very f. to f. grd.
560 - 570	Ss., very f. to f. grd., qtzitic.
570 - 580	Ss., very f. to f. grd.; Sh. gy.
580 - 590	Sh., gy. fissile.
590 - 600	Sh., gy; Ss., very f. to f. grd. Ss.
600 - 650	Ss., very f. to f. grd., limy; Carb. stks.
650 - 710	Sh. gy.; Ss. very f. to f. grd

– LEGEND –

- SHALE
- SANDSTONE
- PEBBLES
- IRONSTONE
- LIMY SANDSTONE
- QUARTZITIC SANDSTONE
- COAL CARBONACEOUS
- BENTONITIC SHALE
- GLAUCONITE

*CONTACT FROM OUTCROP AT DRILLING SITE

FIG. 5

FIG. 3.—Looking downstream northeast along Pouce Coupe River. Lsd. 1 and 2, Sec. 15, T. 80, R. 13, W. 6th.

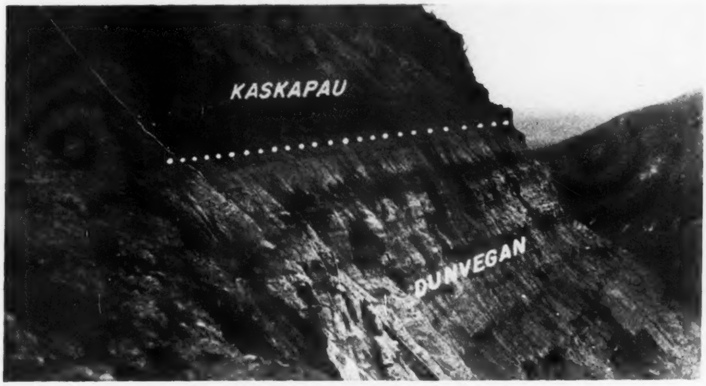


FIG. 4.—Contact well exposed along south bank of Racing Creek along north boundary of T. 78, R. 23, W. 5th.

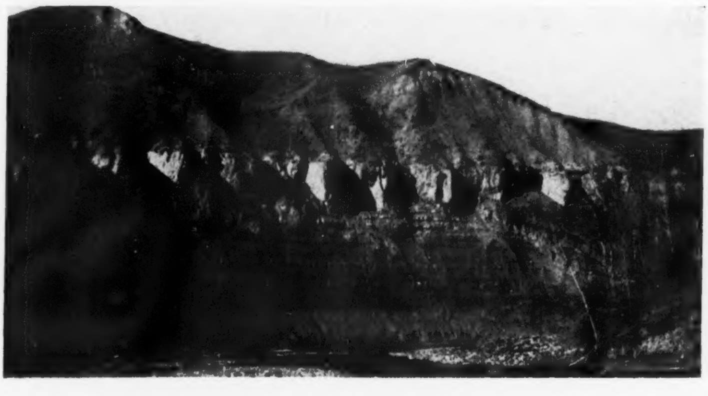


FIG. 6.—Exposure of Pouce Coupe sandstone along north bank of Pouce Coupe River, near mouth of Saskatoon Creek. Lsd. 3, Sec. 30, T. 79, R. 13, W. 6th.

FIG. 7.—250 feet of Kaskapau shales exposed. Dark strata in upper part of shale bank comprise hard platy shale member, Fig. 2. *Inoceramus labiatus* and basal part of White Speckled Shale occur 100 feet above platy shale member, north bank Howard Creek. NE. ¼, Sec. 14, T. 79, R. 6, W. 6th.

FIG. 8.—Exposure of Cardium formation including upper conglomeratic Baytree member, north bank of Cutbank Lake, Sec. 34, T. 77, R. 12, W. 6th.

FIG. 9.—Cardium (Bad Heart) forms prominent ledge in cliff walls of shale along west bank of Smoky River, near mouth of Bad Heart River, north boundary, T. 75, R. 2, W. 6th.

Spirit River; it has a total known thickness of 130 feet and the top occurs 510 feet above the base of the formation. On Smoky River upstream from Watino, the corresponding zone is 100 feet or less above the base. Near the provincial boundary the upper 500 feet of the formation contains several ledge-forming ironstone beds which do not exceed 1 foot in thickness, and at least two burnt shale horizons probably related to the "bocannes" mentioned by Selwyn (25). Near Spirit River, the upper 90 feet of the formation are known to contain at least three ledge-forming ironstone beds. Along Smoky River, the uppermost part of the formation contains similar although somewhat thinner nodular bands.

The formation conformably overlies the brackish- to fresh-water sandstones and shales of the Dunvegan formation. The lower contact has been described and as noted the zone containing the Pouce Coupe and Doe Creek sandstone members is included in the basal part of the formation. The upper contact with the Cardium was not observed in the western two-thirds of the area, but judging from conditions observed along Smoky River, the contact is somewhat abrupt though conformable.

Field evidence shows the Kaskapau has a thickness of 1,550 feet near Pouce Coupe and 900 feet in the vicinity of Spirit River. This implies that the formation thins eastward between the two areas at the rate of 12–15 feet per mile. Between Spirit River town and Smoky River, the thinning is somewhat less per mile because in the latter area J. Y. Smith[5] has found a thickness ranging from 520 to 600 feet.

Faunal zones in the Kaskapau have been fairly well established by McLearn (17) along the Smoky River in the east and by Warren and Stelck (30) along the Pouce Coupe River in the west. Although a complete faunal sequence is not known from either of the two general areas, the writer has traced several faunal horizons from outcrop to outcrop and believes therefore that the zones as indicated by Table II can be accepted throughout most, if not the entire, region. Warren and Stelck (30, p. 144) place the Cenomanian-Turonian boundary just above the Pouce Coupe sandstone containing the *Dunveganoceras* fauna; thus, in the west, the lowermost 300 feet, in the central part the basal 230 feet, and in the east, approximately 75 feet, is Cenomanian in age on this basis.

CARDIUM FORMATION

The term "Cardium" was originally used along the Bow River foothills in Southern Alberta (4, p. 27) where it included two sandstone members separated by sandy shale and thin conglomerate beds. Throughout the foothills, the formation is known to be remarkably persistent as it has been traced several hundred miles north of the Bow River. Eastward, however, the formation thins in a short distance and in wells drilled on the plains near Calgary it is represented only by one or more pebble beds. Far north, as in the plains of the Peace River area, the corresponding beds are at the surface. Here McLearn (10, p. 2C) has applied the

[5] Personal communication.

name "Bad Heart" to a sandstone and pebble bed regarded by the writer as having continuity with the Cardium of Southern Alberta. In this paper, therefore, it is proposed that the use of the name Cardium be extended eastward onto the plains to embrace the Bad Heart member.

The Cardium (Bad Heart) underlies the southern half of the region and forms the abrupt escarpment along the southern part of the plains. The formation is prominently exposed near the provincial boundary, south of the Baytree post-office and along Tupper Creek. It forms a pronounced topographic terrace south of the village of Spirit River, and, along the Smoky and Bad Heart rivers, it stands out prominently as a sandstone ledge in the cliff walls of shale.

In the west, the Cardium may be divided into two members. The lowest member is approximately 50 feet thick and consists of fine-grained, well sorted, marine sandstone. In several places a thin bed of chert conglomerate occurs $1\frac{1}{2}$ feet from the top. The upper member has been called the "Baytree" by Stelck[6] at its type locality south of the Baytree post-office. It consists of a massive black chert and quartzite conglomerate of variable thickness but having a maximum observed thickness of 50 feet. The lowermost part contains cross-bedded lenses of coarse sandstone and fine conglomerate, with sporadic coaly fragments. Pebbles as much as 2 and 3 inches in diameter were observed in the central part of the member, while upward, the pebbles become finer and finer. At one place on Tupper Creek near the provincial boundary a chert pebble bed approximately 1 foot thick was observed in silty shales approximately 10 feet above the highest main conglomerate. This chert is regarded as marking the uppermost limit of the Cardium formation occurring in the region.

In the central and eastern parts of the area the Cardium (Bad Heart) consists of a medium- to coarse-grained sandstone which is dark red in all exposures. The individual quartz grains are mostly clear and subangular. The formation here contains ironstone concretions, some interbedded sandy shale and here and there bands of chert pebbles. The size and number of the pebbles increase westward. Along Smoky River the Cardium (Bad Heart) is capped by a hard calcareous ironstone ledge at least 1 foot thick. The coloration, which is apparently due to inherent characteristics, is one of the best guides in tracing the formation in the field. Where outcrops are only 1 or 2 feet thick, however, care should be exercised in identifying the formation. In the vicinity of Spirit River there are at least three ironstone bands 55–90 feet stratigraphically lower than the one at the top of the Cardium (Bad Heart) on Smoky River. These on exposure yield a similar red coloration to the soil and like the Cardium (Bad Heart) commonly form terraces.

The contact of the Cardium (Bad Heart) sandstone and conglomerate is transitional with the underlying Kaskapau shales along Smoky River. In the same region, its upper contact with the Wapiabi shales is apparently abrupt, but conformable. Elsewhere, neither lower nor upper contacts were observed.

[6] Personal communication.

In the west, near Pouce Coupe, the total thickness of the formation is assumed to be 100 feet, although a complete exposure of both members together (lower sandstone and overlying Baytree conglomerate) was nowhere observed. On the east, along the Smoky River, where upper and lower contacts of the formation were observed, the thickness is 25 feet. Elsewhere, as in the escarpment south of Spirit River, the maximum observed thickness is 15 feet.

On the basis of similar lithologic character and stratigraphic position, the Cardium in the area along the provincial boundary is correlated with the Cardium of the foothills on the south. In the foothills, *Scaphites* cf. *ventricosus* is known to occur in the shales and sandstones of the Cardium and in the shales of the overlying Wapiabi formation. To date this fossil has not been found in the Cardium in the vicinity of Pouce Coupe, although it does occur here in the shales directly above. On the east, however, along Smoky River, the fossil has been found in the sandstone and in the uppermost shales of the underlying Kaskapau. On the basis of faunal evidence, therefore, it may be said that the sandstone along the Smoky River should not be correlated with that on the west as the latter appears to be pre-*Scaphites ventricosus* in age. However, because this fauna has been found within the Cardium of the foothills and because the escarpment effect of the sandstones can be traced across the area from west to east, the writer feels justified in extending the use of the term Cardium eastward to embrace what has been referred to as the Bad Heart.

The presence of such fossils as *Scaphites ventricosus* and *Scaphites vermiformis* indicates Emscherian age (Warren, 29, pp. 110, 111).

WAPIABI FORMATION

The name "Wapiabi" was first applied by Malloch (7) in 1908 to shales above the Bighorn (Cardium) formation in the Bighorn coal basin.

The formation underlies the southern half of the area and for purposes of this paper the formation may be said to form the bedrock throughout the region between the Cardium escarpment on the north and the Wapiti escarpment on the south.

In the vicinities of Pouce Coupe and Spirit River towns very little is known regarding the lithological character of the entire formation because less than a third of it is exposed. Along Tupper Creek near the provincial boundary the lowermost 50 feet consist of fissile, black, marine shale with ironstone concretions. Farther south along the east edge of Swan Lake, there is a littoral marine sandstone and sandy shale member containing glauconite and having a thickness of 75 feet. The top of this member occurs 90–100 feet below the basal sandstone of the overlying Wapiti formation. The writer proposes that the name "Chinook" be applied to this member because it is the same member designated as such by E. M. Spieker.[7] The type locality occurs along the outer foothills belt in the gorge of Fish Creek about ½ mile above the junction with the Wapiti River. The

[7] Personal communication.

Chinook member thins appreciably in an eastward direction, and on the Smoky River, according to Smith,[8] its thickness is approximately 10 feet. The member is ridge forming and commonly forms low terraces within a mile or two north of the more prominent basal Wapiti escarpment. The beds above the Chinook member are transitional with the overlying Wapiti formation and consist of shale and silty shale. Along Albright Creek in the southwest, this zone includes a 6-inch yellow-weathering limestone bed, and cone-in-cone structure is common.

Most of the formation is exposed along the Smoky River where according to Smith[8] the lowermost 140 feet consists of dark gray marine shale overlain by a White Speckled Shale zone at least 20 feet thick. This latter zone probably corresponds with the upper White Speckled Shale zone of the Colorado shales occurring in the Southern Plains of Alberta.

The contact with the underlying Cardium formation in the west is believed to be conformable. The contact was drawn at the base of a 50-foot bed of gray marine shale containing ironstone. The underlying 10 feet of gray silty shales with pebbles was included in the main conglomeratic member of the Cardium. Where observed in the east, the contact with the Cardium (Bad Heart) was even more abrupt but nevertheless still regarded as conformable. Throughout the area, the marine shales of the Wapiabi are transitional with the overlying continental sandstones and shales of the Wapiti throughout a zone at least 90 feet thick. The upper contact is not easily recognizable in outcrop. In the vicinity of Pouce Coupe and Spirit River the writer has arbitrarily placed the contact at the base of a sandy series somewhat continental in appearance. Along the Smoky River, Smith has placed the upper contact of Wapiabi shales at the base of thin bedded, fine-grained sandstones interbedded with shale.

Field evidence shows the Wapiabi has a thickness of 650 feet near Pouce Coupe, and approximately 400 feet near Spirit River. It is estimated that the beds thin 10 feet per mile northeastward. Between Spirit River and Smoky River, the thinning is somewhat less per mile because in the latter area the thickness according to Smith[9] is between 300 and 350 feet.

A *Scaphites ventricosus* fauna occurs in the 50-foot shale bed overlying the Cardium near the provincial boundary. On the east along Kakut Creek a *Baculites ovatus* fauna occurs approximately 210 feet below the top of the formation. The lower part of the formation containing the *Scaphites ventricosus* fauna is regarded as being Emscherian in age (Warren, 29, pp. 110 and 111), while the upper part containing the *Baculites ovatus* fauna is considered Santonian in age (Webb, 31, p. 1407). The formation is correlated with the Wapiabi of the central and southern foothills.

WAPITI FORMATION

The formational name "Wapiti" was first used by G. M. Dawson in 1880 (6, p. 155B) for a group of sandstones, shales, and thin coal seams at the mouth of Big Mountain Creek, 13 miles upstream from the mouth of Wapiti River. A

[8] Personal communication.

[9] Personal communication.

thickness of 1,100–1,300 feet of non-marine strata overlying the Smoky River shales was referred to the Wapiti formation by McLearn in 1918 (10) and Rutherford in 1930 (24). In 1946, these strata were designated "Member A" of the Wapiti formation by Allan and Carr (3).

The lower part of Member A (Allan and Carr, 3) forms the surface rock in the extreme southern part of the area.

Along Albright Creek near the provincial boundary, only approximately the lowermost 100 feet are exposed. These beds consist of fairly massive, buff weathering, coarse-grained sandstones interbedded with shale and thin coal seams. South of Spirit River, the lower 230 feet are predominantly argillaceous, consisting of compact, poorly stratified clayey shales and silts with thin ironstone that weather to variegated colors. Badland type of erosion exposes these beds in the vicinity of White Mountain (T. 77, R. 6) and Woking (T. 75, R. 5). Only the hard sandstone member here and there in the overlying beds withstands erosion and there are therefore large concealed intervals about which nothing is known. Two seams of coal not exceeding 6 inches in thickness were observed at intervals of 100 and 230 feet above the base. These seams have been prospected at a few places but have not proven to be of commercial value. Spring horizons occur at the base and at nearly the same horizons as the coal seams. In such areas as the Heart Valley district south of Wanham and also the settled area south of Birch Hills, the Wapiti beds are known to include good water-bearing zones.

As noted, the formation is transitional with the underlying Wapiabi formation throughout a zone approximately 90–100 feet thick. The contact is not easily recognizable at the outcrop and in the few places where observed the basal beds are silty and argillaceous. Basal beds of the Wapiti are almost everywhere cliff-forming as they withstand erosion to a greater extent than the underlying shales.

The total thickness of Member A is between 1,100 and 1,300 feet (10, 3, and 24) and of this thickness only the lower 630 feet were measured by the writer.

South of Spirit River, dinosaur remains, *Unio* cf. *senectus,* and fossil wood were observed in beds approximately 190 feet above the base of the formation. Near Bezanson Ferry along the Smoky River vertebrate bones occur approximately 500 feet above the base according to Smith.[10] Member A is correlative with the Belly River formation of the foothills in central Alberta and with the lower part at least of the Belly River group of the Plains areas in Southern Alberta.

Paleontology

FAUNA OF DUNVEGAN FORMATION

Fossils in the formation have been discussed by Rutherford and Warren (24, 27) and McLearn (21). The non-marine *Unio* (*Pleurobema*) *dowlingi* McLearn is found in the lower part of the formation throughout the area. According to McLearn (21) the following forms are found in the formation near Dunvegan Ferry.

[10] Personal communication.

TABLE 2

FAUNAL CORRELATION CHART
UPPER CRETACEOUS SURFACE FORMATIONS
WESTERN PEACE RIVER PLAINS
ALBERTA

<table>
<tr><th colspan="2" rowspan="2">EUROPEAN EQUIVALENT</th><th colspan="2">FAUNAL HORIZONS</th><th colspan="2" rowspan="2">FORMATION</th></tr>
<tr><th>Ammonites</th><th>Inocerami</th></tr>
<tr><td rowspan="3">SENONIAN</td><td rowspan="2">SANTONIAN</td><td rowspan="2">Baculites ovatus</td><td rowspan="2">Inoceramus lundbreckensis</td><td colspan="2">WAPITI</td></tr>
<tr><td rowspan="4">SMOKY RIVER GROUP</td><td>WAPIABI</td></tr>
<tr><td>CONIACIAN (EMSCHERIAN)</td><td>Scaphites ventricosus</td><td>Inoceramus pontoni</td><td>CARDIUM</td></tr>
<tr><td colspan="2">TURONIAN</td><td>Watinoceras</td><td>Inoceramus labiatus</td><td rowspan="2">KASKAPAU</td></tr>
<tr><td colspan="2" rowspan="3">CENOMANIAN</td><td>Dunveganoceras</td><td></td></tr>
<tr><td rowspan="2"></td><td>Corbula pyriformis</td><td colspan="2" rowspan="2">DUNVEGAN</td></tr>
<tr><td>Unio dowlingi</td></tr>
</table>

Pelecypoda
- *Corbula pyriformis* var. *dunveganensis* McLearn
- *Corbula* cf. *nematophora* Meek
- *Barbatia micronema* Meek
- *Ostrea anomioides* Meek
- *Modiolus silentiensis* McLearn
- *Inoceramus dunveganensis* McLearn
- *Inoceramus dunveganensis* var. *mcconnelli* Warren
- *Brachydontes multilinigera* Meek*
- *Inoceramus rutherfordi* Warren*

* Forms reported by C. R. Stelck (personal communication).

In this paper, the beds referred to by McLearn containing the *Dunveganoceras* fauna are included in the overlying Kaskapau formation (Table II).

FAUNAS OF SMOKY RIVER GROUP

DUNVEGANOCERAS FAUNA

The first recorded specimen of this type was collected by Rutherford (24) and named *Acanthoceras albertense* Warren. In 1940 Warren and Stelck (30) established the genus *Dunveganoceras* on the basis of this specimen. The writer has observed that *Dunveganoceras albertense* and *Dunveganoceras poucecoupense* occur 300 feet above the base of the Kaskapau formation along Doe Creek and Pouce Coupe River near the provincial boundary. Approximately 50 miles farther east along the Peace River at Dunvegan ferry, the writer has collected *Dunveganoceras albertense* from shales 120 feet above the base. The corresponding zone is believed to have a thickness of 50–75 feet along Racing Creek near Smoky River but no fossils were found. The *Dunveganoceras* fauna includes the following forms.

Pouce Coupe area (basal 300 feet)

Pelecypoda
- *Inoceramus allani* Warren
- *Inoceramus tenuiumbonatus* Warren
- *Inoceramus corpulentus* McLearn
- *Inoceramus corpulentus* var. a. and b.
- *Arctica murrayensis* Warren
- *Pecten* sp.
- *Ostrea* sp.
- *Brachydontes multilinigera* Meek
- *Pinna* sp.

Gastropoda
- Unidentifiable form

Ammonoidea
- *Dunveganoceras poucecoupense* Warren and Stelck
- *Dunveganoceras albertense* Warren and Stelck

Spirit River area (basal 200 feet)

Pelecypoda
- *Arctica murrayensis* Warren
- *Cyrena* sp.
- *Tellina* sp.?
- *Inoceramus allani* Warren
- *Inoceramus* cf. *corpulentus* McLearn
- *Pecten* (young)

Cyrena albertensis Warren
Brachydontes multilinigera Meek
Ostrea dunveganensis Warren
Corbula cf. *nematophora* Meek
Pteria linguiformis var. *borealis* Warren

Gastropoda

Lunatia obliquata Evans and Shumard
Lunatia n. sp.?

INOCERAMUS LABIATUS AND *WATINOCERAS* FAUNAS

This fauna overlies the *Dunveganoceras* fauna and includes the *Inoceramus labiatus* zone as named by Warren and Rutherford (26) and the *Watinoceras* zone as named by McLearn (17). It maintains a fairly uniform thickness of approximately 140 feet across the area. The ubiquitous *Inoceramus labiatus* does not occur abundantly and since *Watinoceras* has been found occurring with this form and in the shales both below and above, the two zones are grouped together for purposes of this report.

This fauna includes the following forms.

Pouce Coupe area

Pelecypoda

Inoceramus sp.
Oxytoma
Inoceramus labiatus Schlotheim
Inoceramus cf. *labiatus* Schlotheim

Gastropoda

Turritella sp.

Ammonoidea

Placenticeras pseudoplacanta Hyatt
Watinoceras sp.

Spirit River area

Pelecypoda

Inoceramus labiatus Schlotheim
Inoceramus cf. *fragilus* M. and H.
Inoceramus tenuiumbonatus Warren
Inoceramus n. sp.

Ammonoidea

Watinoceras? n. sp.
Watinoceras coloradoensis? Henderson
Ammonite not positively identified (*Prionotropis* or *Prionocyclus*)
Scaphites cf. *delicatulus* Warren
Scaphites delicatulus Warren
Scaphites n. sp.

Gastropoda

Unidentifiable form

Pisces

Unidentified scales

Smoky River area

Pelecypoda

Inoceramus corpulentus McLearn
Cyprina sp.
*Inoceramus labiatus** Schlotheim

Ammonoidea

Watinoceras cf. *coloradoensis* Henderson
Watinoceras coloradoensis Henderson
Watinoceras reesidei Warren
*Prionotropis caurinus** McLearn
Scaphites delicatulus Warren

Pisces

Unidentified scales

* Forms reported by McLearn (15) or Rutherford (24).

According to McLearn (17) "*Prionotropis caurinus* McLearn, *Prionotropis hyatti* Stanton, *Prionocyclus* sp., and *Scaphites* n. sp. have been collected from the Kaskapau shale, above the beds containing *Watinoceras*, on Smoky River near the mouth of Little Smoky River." Evidence now suggests that *Watinoceras* ranges upward into beds containing *Prionotropis* and that some form of *Prionotropis* may represent in part a later time than *Inoceramus labiatus* Schlotheim.

SCAPHITES VENTRICOSUS FAUNA

This broad faunal zone has been recognized by Warren and Rutherford (26), McLearn (17), and Webb (31). This fauna overlies the beds containing *Prionotropis* and *Watinoceras* and thus far has been found in the shales underlying and within the Cardium (Bad Heart) and directly above the Cardium.

The list of genera and species from these beds follows.

Pouce Coupe area

Pelecypoda

Inoceramus pontoni McLearn
Inoceramus selwyni McLearn
Inoceramus exogyroides Meek and Hayden
Pteria linguiformis Evans and Shumard
Lingula sp.
Pecten sp.

Ammonoidea

Scaphites ventricosus Meek and Hayden
Scaphites vermiformis Meek and Hayden

Spirit River area

Pelecypoda

Inoceramus cf. *coulthardi* McLearn
Inoceramus pontoni McLearn
Panope sp.?
Oyster sp.
Tellina sp.
Anomia sp.
Liopistha (*Psilomya*) *allani* Warren

Crustacea

Lobster claw

Smoky River area

Pelecypoda

Pecten silentiensis McLearn
Inoceramus pontoni McLearn
Inoceramus coulthardi McLearn?
Inoceramus umbonatus Meek and Hayden

*Inoceramus selwyni** McLearn
*Inoceramus erectus** Meek
Inoceramus exogyroides Meek and Hayden
*Inoceramus albertensis** McLearn
Tancredia sp.
Ostrea anomioides Meek
Protocardia subquadrata Evans and Shumard
Tellina sp.
*Pteria linguiformis** Evans and Shumard
Goniomya cf. *americana** Meek and Hayden
*Oxytoma nebrascana** Evans and Shumard
Pinna dolosoniensis McLearn

Ammonoidea

Baculites cf. *asper** Morton
Scaphites ventricosus Meek and Hayden
Scaphites vermiformis Meek and Hayden

* Forms reported by McLearn (15).

BACULITES OVATUS FAUNA

This fauna has been recognized by McLearn (15) and Warren and Rutherford (24, 26, and 27).

It occurs above the beds containing *Scaphites ventricosus*, and from exposures examined to date along Kakut Creek *Baculites ovatus* Say is known to occur in beds as low as 130 feet above the base of the Wapiabi. In the Smoky River area Smith[11] has observed *Inoceramus lundbreckensis* McLearn and *Ostrea congesta* Conrad in beds 150 feet above the base, and in the same general area *Baculites aquilaensis* and *Baculites ovatus* var. *haresi* Reeside occur 250 feet above the base.

The *Baculites ovatus* fauna is believed to embrace the upper part of the Wapiabi and may extend up into basal Wapiti in places.

To date the following forms are known to occur.

Pouce Coupe area

Pelecypoda

Ostrea sp.
Liopistha undata Meek
Oxytoma nebrascana Evans and Shumard

Spirit River area

Ammonoidea

Baculites ovatus Say*
Baculites compressus Say*?
Desmoscaphites bassleri Reeside*
Baculites trifidolobatus Warren

Smoky River area

Pelecypoda

Nucula sp.
Ostrea congesta Conrad
Inoceramus lundbreckensis McLearn

Ammonoidea

Baculites aquilaensis Reeside
Baculites ovatus var. *haresi* Reeside
Desmoscaphites bassleri Reeside

* Reported by Rutherford and Warren (24 and 27).

[11] Personal communication.

Conclusions

1. The top of the Pouce Coupe sandstone (30) or its equivalents containing the *Dunveganoceras* fauna is regarded as marking the Cenomanian-Turonian boundary. The lower part of the Kaskapau, from top of Pouce Coupe sandstone down to Dunvegan, is therefore considered as uppermost Cenomanian in age.

2. The Smoky River group of the Peace River plains includes the Kaskapau, Cardium (Bad Heart), and Wapiabi formations and is approximately equivalent to the Colorado group, plus the lowest beds of the Montana group, as known in the Central Plains and Rocky Mountain regions of the United States.

3. The fossil zones of the Smoky River group discussed are, in general, the same as those described by McLearn (17 and 21) and Warren and Stelck (30) excepting with regard to the *Dunveganoceras* fauna. The writer believes that the *Dunveganoceras* fauna should be included in the Kaskapau rather than in the underlying Dunvegan formation.

4. The Speckled Shale zone which occurs in the Kaskapau below the Cardium (Bad Heart) in the central and eastern part of the area is considered to be equivalent to the Lower Speckled Shale zone of the Colorado shales in southern Alberta. A higher Speckled Shale zone occurring above the Cardium (Bad Heart) was observed along the Smoky River in the east and is thought to be correlative with the Upper Speckled Shale zone at the top of the Colorado shales in southern Alberta.

5. From field observations and a study of aerial photos, it has been concluded that the Cardium formation extends eastward to the Spirit River and Smoky River areas and embraces what has formerly been referred to as the Bad Heart member by McLearn (10).

6. The Kaskapau, Cardium (Bad Heart), and Wapiabi formations are readily recognizable units throughout the region which extends approximately 90 miles east and west across the Peace River plains in Alberta. They may be correlated almost entirely with the formations established by Malloch (7) in the Bighorn coal basin, namely, the Blackstone shales, Bighorn formation, and Wapiabi shales. The basal part of the Blackstone, however, may contain stratigraphic equivalents of the Dunvegan formation which underlies the Kaskapau.

7. The name Chinook is applied to a littoral marine sandstone and sandy shale member containing glauconite in the upper part of the Wapiabi formation. This member is probably correlative with the Solomon sandstone of the central foothills and the Highwood sandstone of the southern foothills.

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JURASSIC SECTIONS IN FOOTHILLS OF ALBERTA AND NORTHEASTERN BRITISH COLUMBIA[1]

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ABSTRACT

Fourteen stratigraphic sections of Jurassic strata in separate localities along the foothills belt of Alberta and British Columbia are presented. These sections were obtained from outcrop measurements and drill cuttings of borings. The variations in Jurassic stratigraphy in selected localities and the geologic history are discussed briefly.

INTRODUCTION

Jurassic strata crop out in the Rocky Mountains and in the foothills belt in areas extending from Latitude 49° 30′ to 57° 00′. These strata have been designated as the Fernie formation after the locality in which they were first recognized. In the southern foothills the formation overlies, with erosional unconformity, Triassic or Carboniferous strata and consists of a marine sequence of gray to black shales interbedded with minor amounts of thin sandstones; the upper beds grade through a transition zone into the non-marine coal-bearing Kootenay formation of Lower Cretaceous age. Similar lithologic conditions are present in the east-central foothills of Alberta, where the Fernie is overlain by the Nikanassin formation; the latter is correlative in part with the Kootenay, but contains very few coal beds. Recent geological mapping north of the Athabaska River has indicated that the Nikanassin sandstones overlying the Fernie formation are in part marine in origin and contain late Upper Jurassic fossils. The upper part of the Nikanassin formation of this latter region is in part non-marine and contains plant fossils which appear to be correlative with the Kootenay flora; as no erosional disconformity has been recognized in the formation it is probable that there is no lithologic or time break between the Jurassic and Cretaceous systems.

Measured sections of the Fernie formation from outcrop areas and from studies of well samples are presented. The variations in Jurassic stratigraphy in selected localities and the geologic history are discussed briefly.

HISTORICAL SUMMARY OF PREVIOUS WORK

Both R. G. McConnell in 1886 (1) and J. P. McEvoy in 1900 (2) noted the black shales underlying the Cretaceous coal measures but did not designate them as a separate formation. W. W. Leach in 1902 (3) used the term "Fernie shale" for the strata underlying the coal formations in discussing the eastward thinning of Cretaceous strata from Crowsnest to Blairmore, but he did not define the

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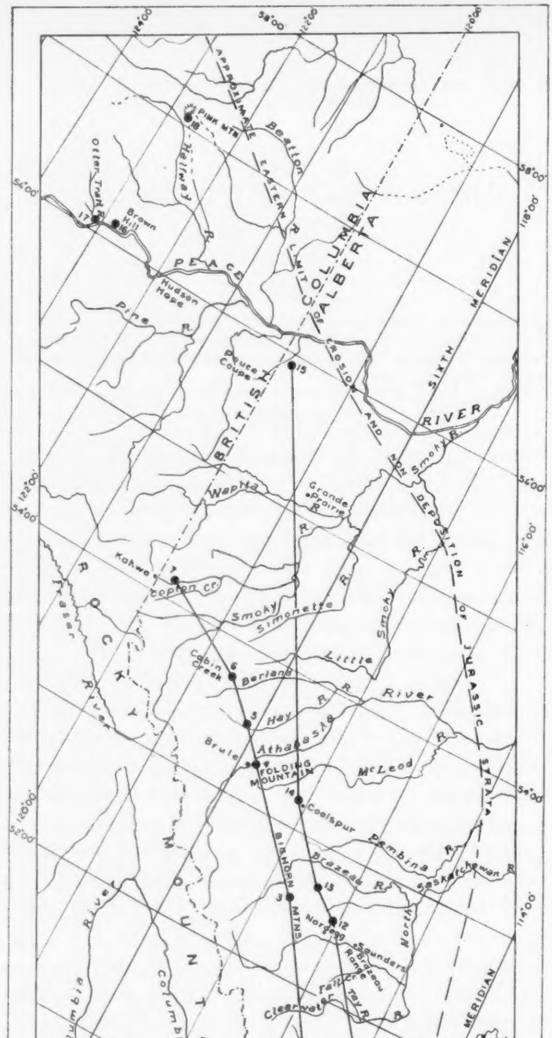

Fig. 1

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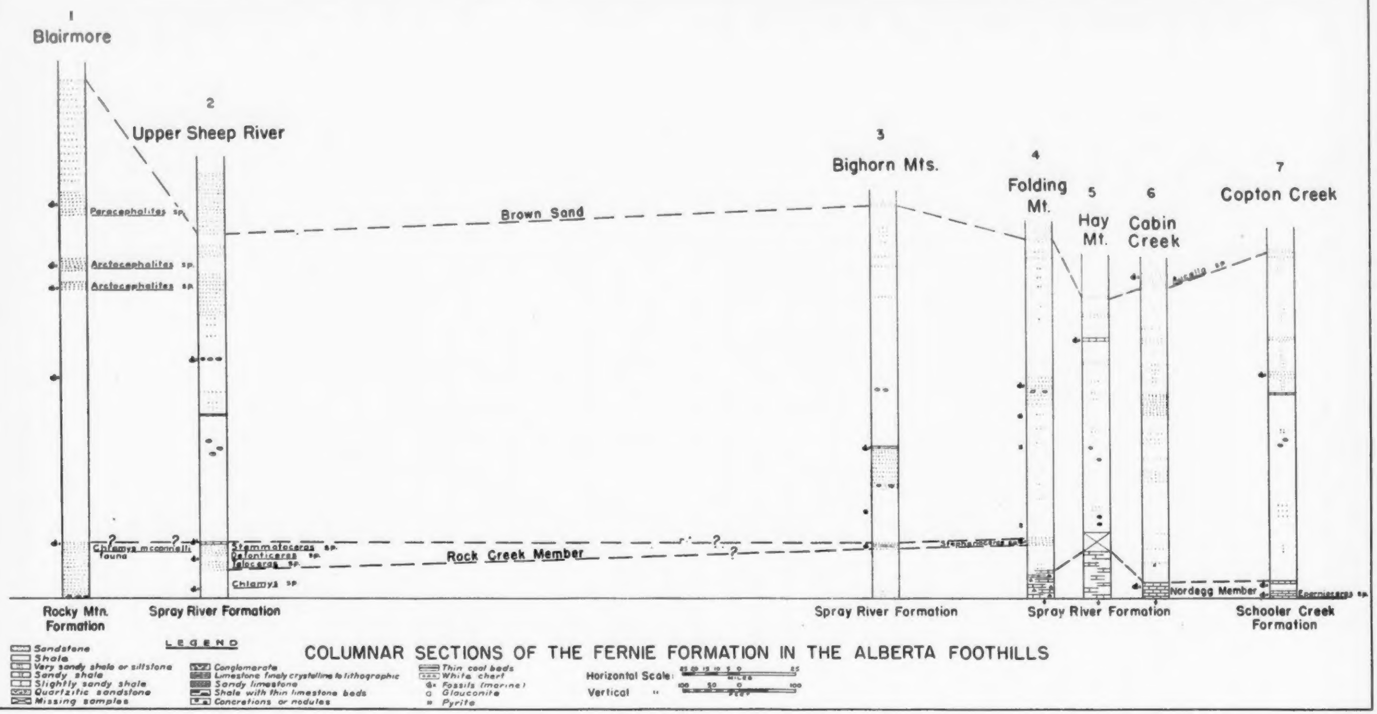
formational boundaries or recognize its Jurassic age. In 1903, J. F. Whiteaves (4) published a description of an ammonite collected by McEvoy from the black shale at Fernie and established the Jurassic age of these strata. Following this identification, geologists of the Canadian Geological Survey recognized the Fernie formation as a distinct lithologic unit and separated it from the overlying Kootenay strata. The stratigraphic paleontology of the Blairmore region was studied by F. H. McLearn in 1914–15 (5) and the detailed fossil descriptions were published in 1928 (6). McLearn also contributed much of the paleontologic knowledge of the Canadian Jurassic fauna in many papers published by the Royal Society of Canada (7). In 1931, C. H. Crickmay (8) discussed the Jurassic of Alberta in conjunction with a regional study of this system in North America. P. S. Warren (9) published several papers on new faunas in the Fernie, and in 1934 (10) summarized the stratigraphic and paleontologic evidence known at that time. In 1944, J. F. Henderson (11) used the term Fernie group for strata of Jurassic age, but stated that some of the upper sandstone beds might belong to the Nikanassin formation. O. A. Erdman (12), in 1945, defined the Fernie group in the Saunders map area as the Jurassic strata between the Rundle formation and the Cadomin formation; he also mapped the Nikanassin strata as part of the Fernie group. In the Brule map area, A. H. Lang (13) used the term Fernie group for Jurassic strata, but mapped the Nikanassin formation as a separate Cretaceous unit although he recognized that the lower beds might be Jurassic and marine in origin.

The Fernie formation in outcrop areas is either poorly exposed or severely folded and faulted so that it is very difficult to measure a complete section. The scarcity of diagnostic fossils has hampered the study and correlation of sections in the Foothills belt.

SECTIONS IN WESTERN FOOTHILLS

Columnar sections of the Fernie formation in seven localities from Blairmore to the Alberta-British Columbia boundary, a distance of 560 miles, are shown in Figure 2. The formation consists predominantly of marine gray to black shales with intercalated sandstone and limestone beds which vary in number and thickness in different localities. No distinct marker beds can be correlated throughout the foothills belt although Warren (10) has indicated two lithologic zones which may be recognized in sections; he has defined these units as the Rock Creek member, a calcareous sandstone 5–30 feet thick occurring 50–150 feet above the base of the formation, and the Black Chert member, which consists of black chert with interbedded shaly layers and lies near the base of the formation. The Black Chert member has been mapped throughout an extensive area in the west-central foothills of Alberta, where in most places it consists predominantly of black limestones and calcareous shales with abundant chert fragments and locally phosphatic nodules; it is well exposed in the Nordegg area and has been called the Nordegg member by geologists of various oil companies.



COLUMNAR SECTIONS OF THE FERNIE FORMATION IN THE ALBERTA FOOTHILLS

Fig. 2

Another lithologic unit easily recognizable in well sections is the Brown sand. This unit has been recognized also in a few outcrop areas, and in well sections it has been considered as the top of the Fernie formation. In field mapping, the first prominent sandstone above the shale zone is considered the base of the Kootenay or Nikanassin formations.

BLAIRMORE DISTRICT

Near Blairmore the Fernie formation lies on the Pennsylvanian Rocky Mountain formation and is approximately 930 feet thick. The basal bed is a 2-foot conglomerate containing limestone and chert pebbles, and this is overlain by 100 feet of dark gray, hard sandstone, with a 6-foot calcareous grit at the top (Lille member). The succeeding 600 feet of beds consist of gray and green shales with fine-grained hard calcareous sandstone beds in the upper part. The shale sequence is overlain by a fossiliferous green glauconitic sandstone, locally 50 feet thick. The top of the section consists of 180 feet of thin-bedded sandstone and shale which is partly non-marine and represents a transition zone below the non-marine Lower Cretaceous Kootenay formation. McLearn called this transition zone the Passage beds.

West of Blairmore the Fernie lies on Lower Triassic strata and the basal beds consist of calcareous phosphate beds. The thickness of the formation has been given as 878 feet by L. Telfer (14) and 800 feet by Warren (10). B. R. MacKay (15) described a section at Corbin and estimated the thickness as 2,800 feet, but Warren suggests that there is duplication by faulting in this area. In the type locality at Fernie, British Columbia, McEvoy stated that there are 3,000 feet of strata in this formation, but recent geologic studies have indicated that an unfaulted complete section is not exposed.

SHEEP RIVER DISTRICT

In the upper Sheep River area near the Burns Mine the Fernie formation lies on Triassic limestone and is 763 feet thick, from its base to the top of the Brown sand. The basal 50 feet consists of black shale containing Belemnites and small pelecypods. This is overlain by 45 feet of interbedded gray quartzitic sandstone and gray shale, and a thin fossiliferous limestone bed which may be correlated with the Rock Creek member. This is overlain by 406 feet of dark gray to black and brown fissile shales, some paper-thin, with concretions, and an interbedded thin limestone and several 1-inch gray, brown-weathering sandstones. The succeeding 145 feet of strata constitutes a transition zone of thin-bedded and platy brown sandstones in beds 2 inches to 3 feet thick interbedded with dark gray shales; this zone may be correlative with McLearn's Passage beds. The top 110 feet consists of brown-weathering gray medium-grained sandstone, of which the basal part is thin-bedded and the upper part ribboned. This sandstone is marine in origin and is correlated with the "Brown sand" of Turner Valley.

West of the Burns Mine in the northwest corner of the Dyson Creek map area (16) the Fernie formation is 422 feet thick and rests on the eroded surface of

the Rundle formation. Near the headwaters of Sullivan Creek in the southern part of the same map area the Fernie rests on Pennsylvanian Rocky Mountain formation. The overlap of the Fernie onto successively older formations is thus well demonstrated.

In the Moose Mountain area the Fernie formation is 220 feet thick and overlies the Rundle formation. The sequence at its base contains a black phosphatic shale-limestone zone overlain by chocolate brown platy shale and black fissile and calcareous shales with some thin limestone beds. The upper part of the formation consists of interbedded dark brown sandy shales and hard brown sandstones with a brown sandstone zone 25 feet thick at the top. In this area there is evidence of an erosional disconformity between the top of the formation and the overlying massive black quartz sandstone which is considered the base of the Kootenay formation. This sandstone has been named the Moose Mountain member by H. H. Beach (17).

BIGHORN MOUNTAIN REGION

The Fernie formation in the Bighorn Mountains region is 722 feet thick (18). It overlies Triassic sandstones and shales which may be correlative with the Spray River formation. The basal member consists of 14 feet of sandstone with calcareous cement, black on fresh surface but white-weathering, and this is overlain by 76 feet of hard black somewhat siliceous shale. This in turn is overlain by a 10-foot gray calcareous sandstone which may be correlative with the Rock Creek member. This latter is overlain by 101 feet of soft black shale containing disseminated pyrite, 71 feet of quartzose sandstone, a 2-foot black limestone band, and 447 feet of black shales which become sandy in the upper part and contain thin sandstone beds. The upper contact was placed at the base of a 10-foot massive sandstone above which the Kootenay (Nikanassin) beds consist of non-marine strata in large part.

East of the Bighorn Mountains in the Brazeau Range area the Fernie formation overlies the Rundle formation and is 270–330 feet thick (19). The lower 120–160 feet consists of black fine-grained cherty and phosphatic limestone which weathers buff. The upper part of the formation consists of light gray buff-weathering sandstone interbedded with black or dark gray shales which vary in thickness and stratigraphic sequence in different parts of the area.

In the Hay River and Fall Creek map areas east of the Brazeau Range, Henderson (11) divided the Fernie into two units with a total thickness of 325–400 feet. The lower unit, 125–150 feet thick, is a thin-bedded, fine-grained platy, black limestone with much interbedded chert. The beds weather buff to gray with a hackly surface and are resistant to erosion. The upper unit consists of 200–250 feet of black shale and sandstone which grades upward into buff- to brown-weathering thickly bedded, medium-grained sandstone probably referable to the Nikanassin formation.

Throughout this region the Fernie formation can not be readily separated

from the Nikanassin and the latter, if present, is very thin. The basal cherty limestone (Nordegg member) of the Fernie formation is well developed here and northward.

FOLDING MOUNTAIN AND ATHABASKA RIVER REGION

In the Folding Mountain region along the Athabaska River the Fernie strata overlie siliceous limestones or dolomites of Lower or Middle Triassic age. The basal Nordegg member is approximately 50 feet thick and is overlain by 45 feet of black shales and 15 feet of brownish gray calcareous fine-grained sandstone (Rock Creek member). This sandstone is overlain by 245 feet of gray shales, pyritic and sandy in part, followed by 50 feet of very fine-grained, hard, calcareous sandstone with thin conglomerate bands, and 250 feet of black shale with thin sandstones. The top of the section is a 20-foot massive light gray, fine-grained buff-weathering quartzitic sandstone which may be equivalent to the Brown sand of the Turner Valley region. This section contains fossils which are early Middle Jurassic in age.

North of Athabaska River, in the Brule map area, Lang (13) gave the thickness of the Fernie section as 1,300 feet although he states that there may be some faulting in the concealed parts. The top of the section is a 6-foot quartzitic sandstone whose upper surface reveals a slight erosional disconformity. Lang notes that the overlying Nikanassin formation, which is 1,000 feet thick, may be marine and Jurassic in age in its lower part.

HAY MOUNTAIN REGION

Approximately 3 miles south of Hay Mountain the Fernie formation overlies Middle Triassic limestones or dolomites and is 538 feet thick. The formation may be divided into three units, the lowest consisting of 84 feet of hard thinly bedded, calcareous black shale and interbedded limestone. The middle member, 187 feet thick, consists of black fissile, non-calcareous shale containing rusty-weathering ironstone beds and concretions. The upper member is 267 feet thick and consists predominantly of shales with minor amounts of fine-grained, gray, brown-weathering sandstone; the sandstone beds increase in number toward the top. A prominent sandstone bed 6 feet thick is considered as the base of the Nikanassin formation.

The lower 750 feet of the Nikanassin formation consists of brown and gray sandstones and dark gray shales with some glauconite. This section is probably marine in origin and contains *Aucella* species which may be late Upper Jurassic in age.

CABIN CREEK REGION

North of the Berland River in the Cabin Creek region, the Fernie formation overlies Middle Triassic limestones and has a thickness of 598 feet. The formation may be divided into three units comparable with those in the Hay Mountain section, but the upper sandy member is thicker. The lowest unit consists of 30

feet of black phosphatic limestone and black shale (Nordegg member). It is overlain by 185 feet of fissile to thin-bedded black shale. The upper unit contains dark brown to light buff sandstones 6–14 feet thick interbedded with black shales.

Pelecypods found in the upper part of the overlying Nikanassin formation were tentatively identified as Upper Jurassic in age, and a large part of the section is probably marine in origin.

COPTON CREEK AREA

The northernmost section which has been studied in any detail is that which crops out near Stinking Springs in the foothills near the Alberta-British Columbia boundary. The Fernie formation is 636 feet thick and overlies Middle Triassic strata with disconformable contact. The section includes the basal Nordegg member, 32 feet thick, consisting of black limestone and calcareous shale with black argillite bands; 341 feet of silty and sandy shales with ironstone concretions; and 263 feet of interbedded sandy shales and sandstones,—the sandstones are fine-grained, cross-bedded and calcareous, and 3–17 feet thick. This section is overlain without apparent lithologic break, by more than 2,000 feet of Nikanassin sandstones and shales which contain Jurassic marine fossils in the lower 1,600 feet. The upper beds contain some aucellids which have been tentatively identified as Lower Cretaceous in age. The age of the Jurassic section ranges from Lower Jurassic (Sinemurian) to probably late Upper Jurassic (Tithonian).

BRITISH COLUMBIA

In the foothills of British Columbia north of Copton Creek, the Fernie formation has been studied in the Peace River region and on Pink Mountain near the Halfway River.

In the Peace River region near Brown Hill (20) the formation is 700 feet thick and consists of dark shales, rare glauconitic shales, and some bands of fine sandstone and impure limestone. The base of the formation is disconformable with the underlying Triassic Schooler Creek formation, and the top is transitional with the overlying Lower Cretaceous Dunlevy formation. Farther west, near the Ottertail River (21), a section 1,100 feet thick consists of black, hackly, fissile shales with thin ironstone bands, interbedded with reddish brown-weathering, fine-grained, dark gray sandstones. No fossils were found in this section and there is no evidence of angular discordance with the underlying Schooler Creek formation.

On Pink Mountain (22) the Fernie formation is 128 feet thick and consists of dark gray to black, calcareous, platy massive shales with several interbedded dark gray limestone beds. The base is marked by 2 feet of argillaceous limestone containing ammonites of Lower Jurassic (Sinemurian) age. The formation overlies the Schooler Creek formation with erosional unconformity. The maximum thickness of the Fernie in this locality is 240 feet.

WELL SECTIONS IN EASTERN FOOTHILLS

The detailed lithologic study of the subsurface Fernie formation and the

recognition of marker beds were first developed in the Turner Valley district of the southeastern foothills. Here the section is approximately 200 feet thick and comprises 5 units which are fairly well developed throughout the district. These units are, in descending order, the Brown sand, the shale zone which contains the Fernie lime band and the Belemnite conglomerate, and the basal Poker Chip shale. The Fernie lime band has not been recognized in many wells outside of the Turner Valley field, but the other markers can be correlated in subsurface sections a considerable distance along the eastern foothills.

Figure 3 shows a line of well sections in the eastern foothills from Pekisko Creek (Township 17) to the Guardian well near Pouce Coupe (Township 80). From the Consumers Co-op No. 1 to the Home-Brazeau-Syndicate well the basal Fernie strata overlie the Rundle formation, indicating an unconformity which represents Pennsylvanian, Permian, and Triassic time. At Coalspur and in the Guardian well the Fernie strata overlie Triassic beds which may be Middle or early Upper Triassic in age.

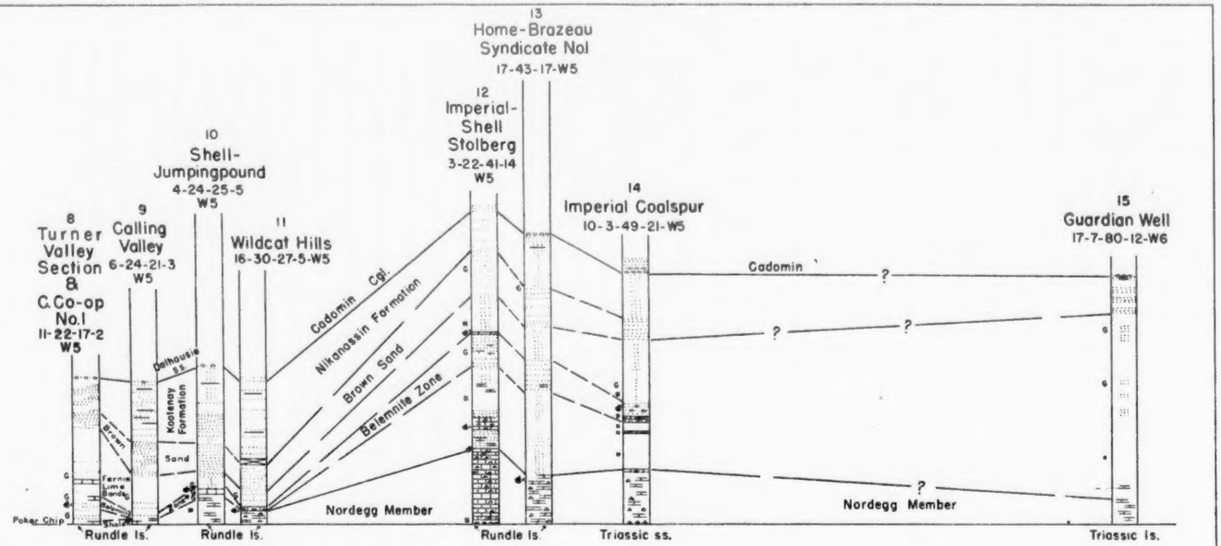
In the wells 8, 9, 10, and 11 (Fig. 3) the basal Fernie beds consist of black calcareous shale with thin limestones, some of which contain chert with white specks; this lithologic unit has a drilled thickness of 6–48 feet and is called the Poker Chip shale. In wells 12, 13, and 14 the correlative basal section is limestone or silty limestone, dark gray brown in color and containing chert with white specks. The thickness varies from 90 to 140 feet and this unit is called the Nordegg member. In the Guardian well the basal 42 feet consists of calcareous shale with a considerable proportion of dark gray limestone, and may be the northern equivalent of the Nordegg member.

The basal unit in this group of wells is overlain by shales, silty, black, pyritic, fissile and somewhat calcareous, containing thin sandstone beds. The section varies in sandstone content from well to well and is 30–320 feet thick. This zone contains a marker bed which has been identified in all the sections excepting the Guardian well; this is the Belemnite conglomerate zone which consists of gray, fine-grained sandstone, with some calcareous shale, limestone fragments, glauconite, and fragments of belemnite guards. This zone varies in drilled thickness from 8 to 60 feet and its position in the section varies from well to well.

The uppermost unit of the Fernie formation is the Brown sand. It consists of fine-grained light brown, quartzose, well sorted sandstone containing glauconite grains locally, and varies in drilled thickness from 30 to 80 feet.

The total drilled thickness of the Fernie formation ranges from 110 to 500 feet.

The Fernie formation is overlain by 60–150 feet of sandstones and shales which have been assigned to the Kootenay or Nikanassin formation. The top of this zone in every section is marked by a conglomerate or conglomeratic sandstone variously known as the Dalhousie sandstone, the lower Blairmore conglomerate, or the Cadomin conglomerate. This is shown in Figure 3 merely to indicate a major unconformity within the Cretaceous section and because it has



WELL SECTIONS OF THE FERNIE AND KOOTENAY (NIKANASSIN) FORMATIONS IN ALBERTA

LEGEND

- Sandstone
- Shale
- Very sandy shale or siltstone
- Sandy shale
- Slightly sandy shale
- Quartzitic sandstone
- Missing samples
- Conglomerate
- Limestone finely crystalline to lithographic
- Sandy limestone
- Shale with thin limestone beds
- Concretions or nodules
- Thin coal beds
- White chert
- Fossils (marine)
- Glauconite
- Pyrite

Horizontal Scale: Miles

Vertical " : Feet

Fig. 3

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been suggested by some geologists that this represents the true time break between the Jurassic and Cretaceous systems.

PALEONTOLOGY AND GEOLOGIC HISTORY

Figure 4 indicates the present extent of our knowledge of the correlation with European Jurassic stages of the Jurassic system as represented by faunas in sections in the foothills of Alberta and British Columbia, and their correlation with the Montana sections (24). The earliest fauna found in any locality is Sinemurian in age and because this represents basal strata in every locality it would appear that the Jurassic seas did not extend over the Rocky Mountain geosyncline until this time. Faunas of the Pliensbachian stage have not been definitely dated by means of ammonites, but it is believed that the pelecypod assemblage shown in the chart is probably of this age. Toarcian faunas have been found in four widespread localities. The Bajocian fauna is the best known in the Fernie formation at the present time. Bathonian faunas have been found in the Fernie formation in upper Sheep River area in Alberta and in the Sweetgrass Arch area of Montana. Callovian faunas are fairly well represented in various localities. Only one Divesian form has as yet been found and Argovian forms are found in three localities.

The occurrence of these fossils in widely separated areas and their ranging in time from Sinemurian to Argovian suggests that the Jurassic seaways were fairly continuous at least in the deeper parts of the Rocky Mountain geosyncline, but this would not necessarily rule out the existence of local uplifts in restricted localities such as possibly the Moose Mountain region.

The presence of pelecypods *Aucella* and *Echinotis*, which have been designated as late Upper Jurassic forms, is noted in the sandstones of the lower part of the Nikanassin formation in the region from the Hay River to Copton Creek and possibly as far north as the Peace River region. This would indicate that the Jurassic seas remained longer in this region than farther south where there is no correlative marine section in the lower part of the Kootenay formation.

In 1914–1915, McLearn (5) suggested that the Passage beds and possibly the overlying Kootenay beds in the Blairmore region represented Jurassic deposition and that the basal Blairmore conglomerate marked the beginning of Cretaceous deposition, with a considerable unconformity between the Jurassic and Cretaceous systems. In 1928, after the Kootenay flora had been assigned a Lower Cretaceous age by Berry, McLearn (6) abandoned this suggestion. W. A. Bell (26) also proposes a Lower Cretaceous age for the Kootenay formation. In 1946, R. W. Brown (23) of the United States Geological Survey studied the flora of the Montana Morrison and Kootenai formations and comparable Canadian fauna, and on the basis of this as well as lithologic grounds revived the suggestion that the Jurassic-Cretaceous boundary should be placed at the base of the Blairmore formation. If further work in the northern foothills corroborates the presence of marine fauna of very late Upper Jurassic age in the Nikanassin formation, and

	EUROPEAN STAGE	INDEX FOSSILS	Fernie, B.C.	Blairmore	Sheep River	Moose Mountain	Lake Minnewanka	Banff	Red Deer River	Clearwater River	Bighorn Mountains	Nordegg-Brazeau	Cadomin	Folding Mountain	Jasper	Copton Creek	Pink Mountain, B.C.	Montana-Sweetgrass Arch	
UPPER	Tithonian	Aucella?														x		Morrison	
	Portlandian																		
	Bononian																		
	Havrian																		
	Sequanian																		
	Argovian	Cardioceras	x									x	x					Swift	x
	Divesian	Quenstedtoceras											x						x
	Callovian	Peltoceras?							x									Rierdon	
		Paracephalites		x															
		Kepplerites (Seymourites)					x	x											
		Proplanulites			x						x					x			x
		Cadoceras			x														x
MIDDLE	Bathonian	Arctocephalites		x	x													Sawtooth	x
		Cranocephalites																	x
		Arcticoceras			x														x
	Bajocian	Itinsaites											x						
		Kanastephanus											x						
		Sonninites											x						
		Defonticeras (Saxitoniceras)			x								x		x				
		Stemmatoceras			x	x							x		x				
		Teloceras	x		x								x						
		Zemistephanus			x	x													
		Stephanoceras												x					
LOWER	Toarcian	Grammoceras	x																
		Harpoceras				x										x			
		Dactylioceras				x									x				
		Hammatoceras													x				
		Catulloceras													x				
	Pliensbachian	Chlamys mcconnelli fauna?		x						x									
		Oxytoma cygnites		x						x		x							
		Ostrea sp.		x						x		x							
	Sinemurian	'Arnioites'	x														x		
		Eparnioceras						x								x			
	Hettangian																		

Fig. 4 J. Spivak

younger beds of the same formation contain marine Cretaceous fauna as well as non-marine Cretaceous flora, then there is no apparent disconformity between the Jurassic and Cretaceous systems and the boundary must be placed well below the base of the Blairmore. This problem must, however, await further study and field work.

From a regional viewpoint the lithologic character of the Jurassic system appears to indicate continuous deposition without any marked breaks or erosion intervals. The marker beds or zones which can be recognized in various localities are not well defined, and for the present at least it is not considered advisable to separate them into units of formational status. The marine sequence of shales up to and including the transitional zone and Brown sand may be considered as constituting the Fernie formation of Jurassic age. In the northern foothills where the Nikanassin formation is composed in part of marine strata containing both Upper Jurassic and Lower Cretaceous fossils, it may be well to consider this formation as ranging in age from Upper Jurassic to Lower Cretaceous.

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MARINE JURASSIC FORMATIONS OF SOUTHERN ALBERTA PLAINS[1]

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ABSTRACT

The Jurassic sediments of the Southern Alberta Plains, known only from subsurface work, are described as to lithology, thickness, distribution, stratigraphic relationships, and geologic history. The three-fold subdivision of the Ellis group into Swift formation, Rierdon formation, and Sawtooth formation, established in Montana, is recognizable and applicable in Alberta. A major unconformity between the Jurassic beds and the underlying Paleozoic limestone influences the distribution of the Sawtooth formation. Late Jurassic or early Cretaceous erosion truncating the Jurassic formations from south to north has determined the present extent and northern boundaries of these formations in Southern Alberta.

INTRODUCTION

No outcrops of Jurassic beds occur in the Southern Alberta Plains region. The presence of beds of Jurassic age at depth has been recognized since 1919. These beds have been referred to the Ellis formation by petroleum geologists in Alberta, but have been left nameless in most Geological Survey of Canada publications. The Ellis in Southern Alberta rests unconformably on limestones of Mississippian age and is overlain unconformably by continental deposits of Lower Cretaceous age. The unconformity at the base of the Cretaceous bevels the Jurassic beds northward until Lower Cretaceous deposits rest directly on the Mississippian limestones.

During 1942, the California Standard Company commenced drilling activities in the Southern Alberta Plains region, and during the following 3 years gained much additional evidence on the distribution and stratigraphy of the Ellis beds in Southern Alberta. During 1942 and 1944, W. A. Cobban[3] of the Carter Oil Company investigated outcrop sections of the Ellis in the Sweetgrass arch area of Montana and demonstrated a three-fold subdivision of the Ellis group which he further recognized in subsurface studies across the Sweetgrass arch.

During 1944, the writer had opportunity to see the results of Cobban's work on the Ellis group in Montana and found them readily applicable to the Jurassic

[1] Read before the Alberta Society of Petroleum Geologists, December 20, 1945. Manuscript received, February 4, 1948. Published by permission of the California Standard Company.

[2] Chief geologist, the California Standard Company. The writer is deeply indebted to W. A. Cobban of the Carter Oil Company for permission to study the results of his stratigraphic work on the Ellis group in Montana. Cobban's field work and subsurface studies in Montana have made possible the understanding of Ellis stratigraphy in Southern Alberta.

J. M. Kirby, chief geologist for the California Standard Company, called attention to the importance for petroleum accumulation of the distribution of the Sawtooth (basal Ellis sands) formation in Southern Alberta.

G. M. Furnival, formerly district geologist at Taber for the California Standard Company, established correlations within the Ellis group. Acknowledgment is made to the California Standard Company for permission to publish the data presented herein.

[3] W. A. Cobban, "Marine Jurassic Formations of Sweetgrass Arch, Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 9 (September, 1945), pp. 1262–1303.

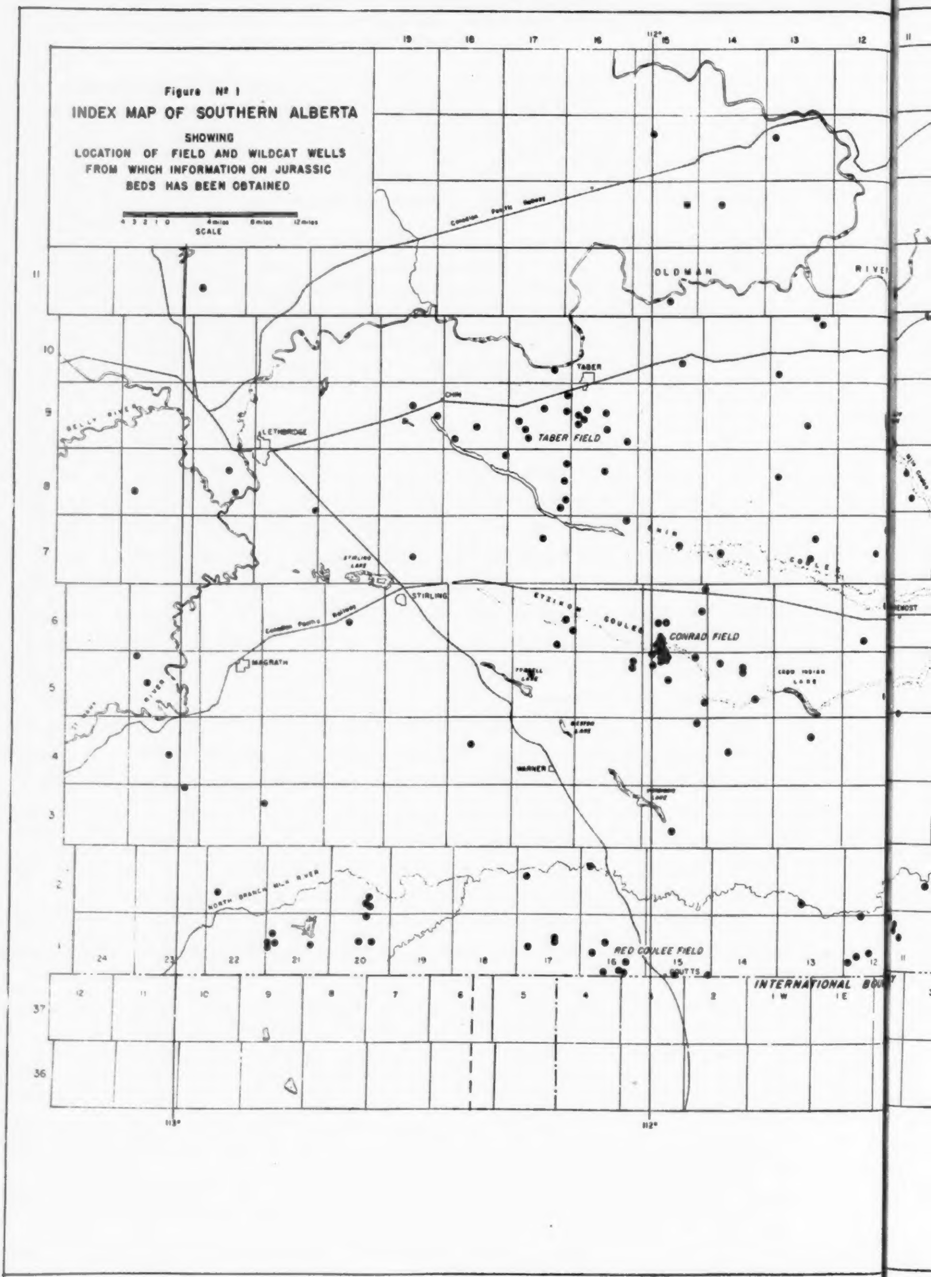
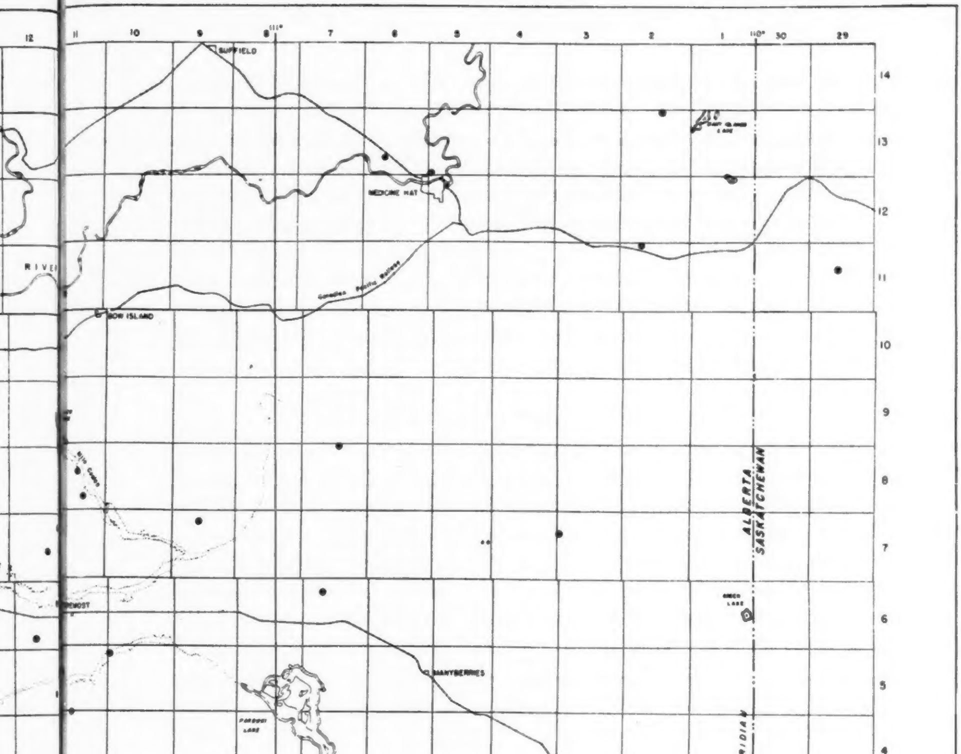


FIG. 1.—Index map of Southern Alberta showing location of field an ldcat w



f field an dcat wells from which information on Jurassic beds has been obtained.

stratigraphic sections established in Southern Alberta by geologists of the California Standard Company.

This paper is thus supplementary to Cobban's paper on "The Marine Jurassic Formations of Sweetgrass Arch, Montana."[4] Its purpose is to show that his subdivision of the Ellis group into three formations can be recognized in Southern Alberta, and further to show the distribution and northern eroded edges of these formations in Alberta.

Cuttings and cores of all but the most recent wells drilled to the Ellis in Southern Alberta have been examined with a binocular microscope. Cuttings of a number of representative wildcat and field wells in Montana adjacent to the Alberta border were also examined.

PREVIOUS INVESTIGATIONS IN ALBERTA

No detailed study of the Jurassic in the Southern Alberta Plains has been published. The presence of a Jurassic section on Sage Creek in the Sweetgrass Hills early suggested that Ellis beds would be found in Southern Alberta. Dowling Slipper, and McLearn[5] in 1919 recognized the presence of Jurassic beds in the Grand Trunk Pacific well in Sec. 1, T. 1, R. 12, W. 4th Mer. Sanderson,[6] in 1931, described the Sage Creek section, and Yarwood[7] in the same publication recognized the Ellis formation in the Red Coulee field. Jurassic beds called Fernie were also recognized by Yarwood[8] in the Spring Coulee well. Williams and Dyer[9] listed nine wells which had penetrated Jurassic beds, seven of these along the Montana border and one at Medicine Hat and one near Many Island Lake. Russell[10] stated that in Southern Alberta the Mississippian limestones were overlain by dark shales of Jurassic age and published four well logs to illustrate the section present. He redescribed the Sage Creek section and agreed that the Jurassic beds of Southern Alberta could be correlated with the Ellis formation of Montana.

LOCATION OF RECENT DRILLING

The search for oil in Southern Alberta during the war years has resulted in the drilling of 80 wildcat wells and 35 field wells at Conrad and Taber, following the discovery of oil in sands at the base of the Ellis group near Conrad, Alberta, and in sands of Lower Cretaceous (Aptian) age unconformably overlying the

[4] W. A. Cobban, *op. cit.*

[5] D. B. Dowling, S. E. Slipper, and F. H. McLearn, "Investigations in the Gas and Oil Fields of Alberta, Saskatchewan, and Manitoba," *Canada Geol. Survey Mem. 116* (1919), p. 49.

[6] J. O. G. Sanderson, "An Ellis (Upper Jurassic) Section at East Butte, Sweetgrass Hills, Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1931), pp. 1157–60.

[7] W. S. Yarwood, "Stratigraphy of Red Coulee Oil Field," *ibid.*, pp. 1166–69.

[8] W. S. Yarwood, "Stratigraphy of the Spring Coulee Well," *ibid.*, pp. 1275–76.

[9] M. Y. Williams and W. S. Dyer, "Geology of Southern Alberta and Southwestern Saskatchewan," *Canada Geol. Survey Mem. 163* (1930), p. 12.

[10] L. S. Russell and R. W. Landes, "Geology of the Southern Alberta Plains," *ibid.*, *Mem. 221* (1940), pp. 13–16.

Ellis at Taber (Fig. 1). Practically all of these wells were drilled with rotary rigs. It has been general practice to core the base of the Cretaceous and top of the Jurassic and the basal Jurassic beds. In a few instances long cored sections of the Jurassic are available. The remainder of the Jurassic beds are represented by cuttings. Drilling-time records for each foot of hole were kept on all California Standard Company wells, and Halliburton electrologs were run on most wells at a scale of 1 inch equals 20 feet.

PALEOZOIC TOPOGRAPHY

The Ellis group rests unconformably on limestone of Mississippian age. Irregularities in the surface of the limestone have influenced the distribution and thickness of members of the Sawtooth formation and basal beds of the Rierdon formation. Local relief on this unconformity is appreciable in many places and must be kept in mind when considering distribution and isopach maps of the Jurassic formations in Southern Alberta, which have also been influenced by the unconformity at the top of the Ellis group. Relief of the limestone surface was sufficient to produce islands in the Sawtooth sea over which the Rierdon shale rests directly on the Paleozoic limestone with no intervening Sawtooth beds.

SAWTOOTH FORMATION

The Sawtooth formation has been defined by Cobban in Montana where he has shown that it consists of a basal sandstone member, a median shale member, and an upper siltstone or sandstone member. The formation can be traced directly into Alberta where it was at first called the "basal Ellis sand" by the writer.

In Alberta the top of the formation is marked by a bed of green shaly sand or sandy shale 1–3 feet thick, containing scattered chert pebbles, broken and rolled belemnite guards, and numerous *Gryphea* and *Ostrea* shells. It is known in Alberta as the Belemnite conglomerate and forms an excellent marker-horizon. Cobban[11] mentions the occurrence of chert pebbles in many localities east of the Kevin Sunburst dome and in one well at Cutbank at what seems to be the same horizon. Beneath the Belemnite conglomerate is a widespread sandstone member varying in thickness from 1 to 30 feet. The local relief on the buried Paleozoic surface influences the thickness of this sand and against limestone ridges it thins to nothing. This sand produces oil at Conrad and has been termed the Conrad sandstone. It is white quartz sandstone, fine- to medium-grained, and well sorted. It is locally lime-cemented or shaly and greenish. Where clean it forms an excellent reservoir with porosities up to 25 per cent and permeabilities up to 3,100 millidarcys at Conrad.

The Conrad sandstone is underlain by a shale member 12–14 feet thick in the area south of Conrad. This shale is dark green and non-calcareous. In the eastern areas of Southern Alberta this shale member appears to interfinger with buff

[11] Cobban, *op. cit.*, p. 1273.

oölitic limestone beds and the three-fold subdivision of the formation is not readily recognizable.

Beneath the medial shale member in the area south of Conrad, a basal sandstone member, similar to that in Montana, is recognizable. The thickness of this member varies between 15 and 20 feet. The sand is quartzose, pale gray or greenish gray, with increase in shaly cement, and is fine-grained. It has been named the Crow Indian Lake member by G. M. Furnival from the Dominion Oil Company's Crow Indian Lake Province well No. 1, in Lsd. 6, Sec. 27, T. 4, R. 13, W. of 4th Mer. North of the Conrad area the section becomes more sandy and the three-fold division of the Sawtooth formation is not developed.

The distribution of the Sawtooth formation and its members is determined by irregularities in the surface topography of the underlying Mississippian limestone which may have considerable relief locally. In general, sandstone members of the formation are not recognized west of a line from Coutts to the Little Bow River. Shale members may be present which have not been differentiated from the overlying Rierdon because of the absence of the Belemnite conglomerate and lack of detailed work on rotary cuttings. The northern extent of the formation is determined by pre-Blairmore erosion. In general the northern eroded edge of the formation follows the trend of the Oldman and South Saskatchewan rivers eastward from the Little Bow, but passing north of Medicine Hat and Many Island Lake. In this general area islands devoid of sand are known where the Rierdon rests directly on limestone.

A typical section showing the three members of the Sawtooth formation follows.

California Standard Company's Conrad Province No. 1

NE. ¼ of Lsd. 8, Sec. 11, T. 5, R. 15, W. 4th Mer.

	Depth (Feet)	*Thickness (Feet)*
Sawtooth formation		
Sandstone member		
Shale, green, very silty, grading down into sandstone, shaly, fine-grained, pyritic, calcareous, a few brown ironstone concretions, numerous belemnites and fragments of *Gryphea*	2,980–2,983	3
Sandstone, fine-grained, quartzose, grains well rounded	–2,990	7
Shale, dark green, calcareous	–2,992	2
Sandstone, dark gray, fine-grained, calcareous, quartzose, tight	–2,999	7
Sandstone as above with dark green shale laminae	–3,001	2
Sandstone, gray, fine-grained, calcareous, quartzose, pyritic	–3,002	1
Shale member		
Shale, dark green, pyritic, scattered small lenses of sand as above, scattered fossil fragments	–3,014	12
Sandstone member		
Sandstone, gray, fine-grained, calcareous, pyritic, quartzose	–3,029	15
Sandstone, as above, glauconitic in places, irregularly bedded. Contact with Madison is narrow irregular band of pyrite	–3,031	2
Total thickness of Sawtooth		51
Unconformity		
Madison limestone		

A section of the Sawtooth formation in the producing area of Conrad field follows.

California Standard Company's Conrad Province No. 2
SE. ¼ of Lsd. 1, Sec. 5, T. 6, R. 15, W. 4th Mer.

	Depth (Feet)	*Thickness (Feet)*
Sawtooth formation		
Sandstone member		
Sandstone, gray, fine-grained, quartzose, shaly, pyritic, a few brown ironstone nodules, many belemnite and pelecypod fragments	2,964	2
Shale, dark gray, pyritic and gray, fine-grained sandstone	-2,965	1
Sandstone, fine-grained, quartzose, porous, well sorted	-2,969	4
Sandstone, dark gray, fine-grained, shaly	-2,969.5	0.5
Shale, dark green	-2,969.7	0.2
Sandstone, white to gray, fine-grained, quartzose, calcareous	-2,969.72	2.3
Total thickness of Sawtooth		10
Unconformity		
Madison limestone		

RIERDON FORMATION

Cobban has defined the Rierdon formation as a group of alternating gray calcareous shales and limestones overlying the sandy beds of the Sawtooth and disconformably underlying the dark micaceous shale and sandstone of the Swift formation. This definition is directly applicable to the beds in Alberta excepting that over much of the area the Swift beds have been removed by pre-Blairmore erosion and the Blairmore rests directly on the eroded surface of the Rierdon. The Rierdon shales and argillaceous limestones are characteristically greenish in color where encountered in Southern Alberta.

Thickness and distribution.—The thickness and distribution of the Rierdon formation in Southern Alberta is shown in Figure 2. Only in the south where shales of the Swift are still preserved does the formation show original thicknesses. In the north pre-Blairmore erosion has thinned the formation as shown. The northern margin is approximate and probably more irregular than drawn. Irregularities in the topography of the limestone surface also contribute to thinning of the formation.

Lithologic character.—Shales of the Rierdon in Alberta are characteristically greenish gray or dull olive-green and calcareous. They grade imperceptibly into argillaceous limestone beds, generally 1–3 feet thick. Individual limestone beds have considerable lateral extent. The presence of a medial dark gray non-calcareous member has not been recognized in Alberta but this may be due to lack of coring in this part of the section.

Following is a typical section of the Rierdon shale at Conrad.

California Standard Company's Conrad Province No. 1
NE. ¼ of Lsd. 8, Sec. 11, T. 5, R. 15, W. 4th Mer.

	Depth (Feet-Inches)	*Thickness (Feet-Inches)*
Swift formation		
Disconformity		
Rierdon formation		
(Drilled) Shale, dark green, calcareous	2,873–2,876	3

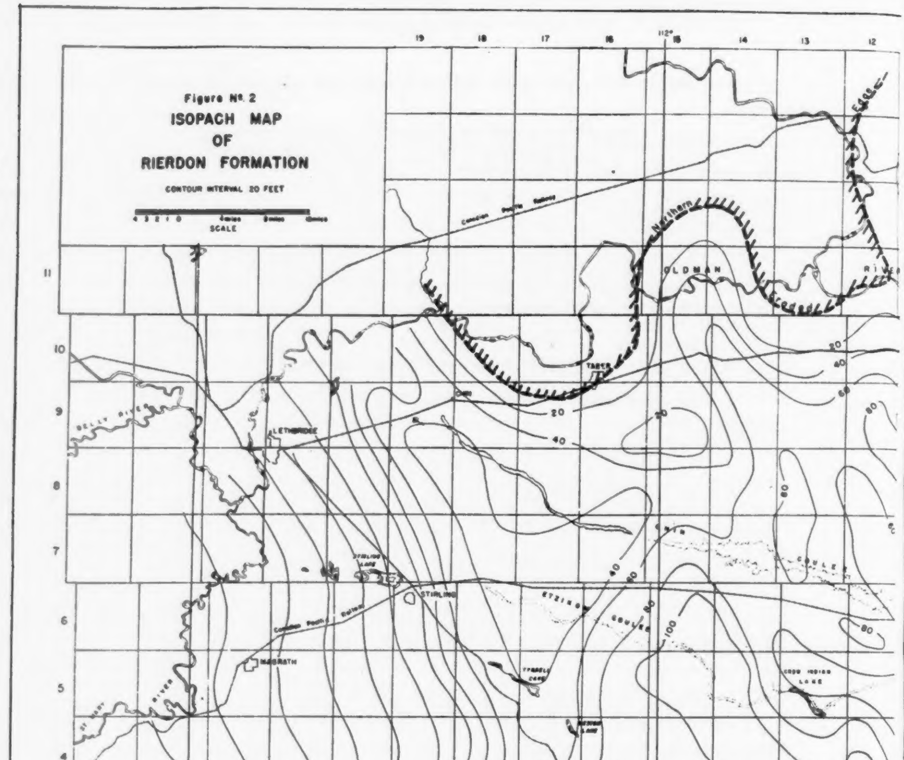
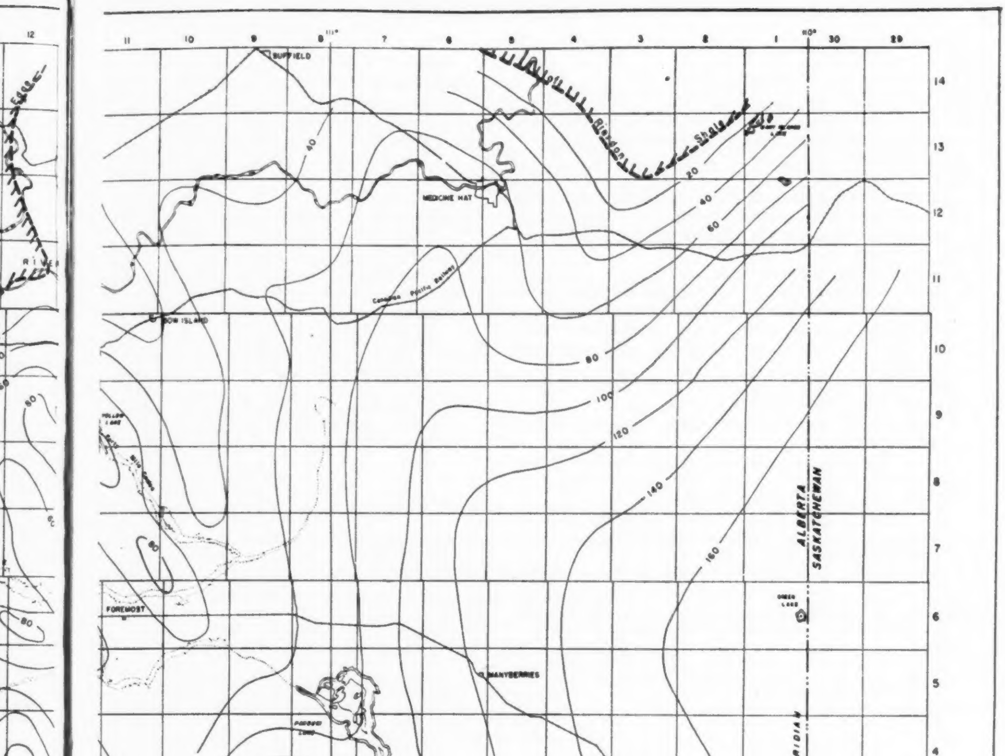


FIG. 2.—Isopach map



h map

of Rierdon formation.

	Depth (Feet-Inches)		Thickness (Feet-Inches)	
(Cored) Shale, green, uniform, brittle, calcareous, soft when wet, numerous small pyrite crystals	−2,881		5	
(Drilled) Shale, dark green	−2,909		28	
(Cored 2,909–2,980)				
Interbedded shale, dark green, uniform, hard, and shale, greenish, gray, calcareous	−2,939		30	
Shale, dark green, hard, slightly pyritic, a few fossil fragments	−2,941		2	
Shale, dark green, calcareous, hard	−2,943		2	
Shale, dark green, a few pyritic nodules and brown ironstone concretions, trace fossil fragments	−2,945		2	
Shales, green, calcareous, hard, interbedded with shales, dark green, softer, pyritic, scattered fossil fragments	−2,958		13	
Shale, dark green, brittle, a few small pyrite nodules and brown ironstone concretions	−2,960	4	2	4
Shale, green, calcareous, a few specks of glauconite	−2,960	9		5
Shale, green, pyritic	−2,961			3
Shale, greenish, calcareous, pyritic, abundant glauconite	−2,962	2	1	2
Shale, green, pyritic, fossil fragments	−2,963	9	1	7
Shale, green, silty, pyritic, brown ironstone concretions, glauconite, fossil fragments	−2,967	1	3	4
Shale, green, silty, calcareous, pyritic	−2,967	9		8
Shale, green, silty, pyritic, brown ironstone concretions	−2,971		3	3
Shale, dark green, hard, pyritic, becomes silty towards bottom, a few belemnites and *Gryphea*	−2,972	2	1	2
Shale, green, calcareous belemnites and *Gryphea*	−2,973	5	1	3
Shale, dark green, hard, scattered pyrite crystals, slightly silty, fossiliferous	−2,978	3	4	10
Shale, green, hard, pyritic, calcareous	−2,979	1		10
Shale, dark green, hard, very finely pyritic, fossiliferous	−2,980	4	1	3
Total thickness of Rierdon formation			107	
Sawtooth formation				

A section of the Rierdon shale cored at Taber follows.

Standard Oil Company of British Columbia's Taber Province No. 1

Center of Lsd. 9, Sec. 18, T. 9, R. 16, W. 4th Mer.

	Depth (Feet-Inches)		Thickness (Feet-Inches)	
Blairmore formation				
Unconformity (Swift and upper part of Rierdon missing)				
Shale, pale green, splintery, very pyritic	3,174–3,176	6	2	6
Shale, pale green, pyritic, soapy textured	−3,177	9	1	3
Limestone, pale greenish gray, argillaceous, very fine-grained, mottled, slightly pyritic	−3,178	2		5
Shale, pale green, pyritic, calcareous	−3,179	2		12
Limestone bed as above	−3,179	5		3
Shale, pale green, pyritic, calcareous	−3,182	9	3	4
Limestone bed as above	−3,183	6		9
Shale, pale green, pyritic, calcareous	−3,184	7	1	1
Limestone bed as above	−3,184	11		4

	Depth (Feet-Inches)		*Thickness (Feet-Inches)*	
Shale, pale green, pyritic, calcareous	−3,185	8		9
Limestone, as above	−3,186			4
Shale, as above	−3,187		1	0
Shale, pale green, splintery, slightly calcareous, finely pyritic, contains belemnite guards	−3,193	6	6	6
Limestone, argillaceous, pale greenish gray, pyritic, mottled	−3,194	4		10
Shale, pale green, slightly calcareous	−3,198	5	4	1
Limestone, as above	−3,198	10		5
Shale, pale gray-green, more calcareous and more pyritic than above	−3,203		4	2
Limestone as above	−3,203	3		3
Shale, pale green, pyritic, with thin partings of black crumbly shale	−3,206		2	9
Total thickness of Rierdon shale			32	
Sawtooth formation				

SWIFT FORMATION

The Swift formation has been defined by Cobban to include dark gray, micaceous, non-calcareous shales and overlying thin-bedded glauconitic sands with partings of dark gray micaceous shale. Over the South arch in Montana an unconformity occurs at the base of the formation. Along the mountain front and over the Kevin Sunburst dome a glauconitic zone with scattered chert pebbles marks the contact with the underlying Rierdon formation. In Southern Alberta the glauconite zone with chert pebbles has been recognized in cores at a number of localities and apparently persists as far north as the formation now extends. Both the basal shale member and the upper Ribbon member are well developed in Southern Alberta. The contact with the underlying Rierdon formation in this area is apparently disconformable. No angular unconformity has been recognized.

Thickness and distribution.—The thickness and present distribution of the Swift formation in southern Alberta are shown in Figure 3. The formation is restricted in extent because of pre-Blairmore erosion. It is doubtful if the original thickness is anywhere shown.

Lithologic character.—The basal shale member of the Swift is dark gray, non-calcareous. At the base it becomes very glauconitic so that small patches are bright green in color. The glauconite zone contains black polished chert pebbles up to $\frac{1}{4}$ inch in diameter. These pebbles are widely scattered and are not readily found in rotary cuttings, but appear in cores. The shale grades upward with a transitional contact into the overlying Ribbon member.

Chert pebbles have been observed at the base of the Swift formation in cores from wells in the following localities.[12]

[12] Core descriptions by the writer. Published by permission of McColl-Frontenac Oil Company Limited, exploration department, Calgary, Alberta.

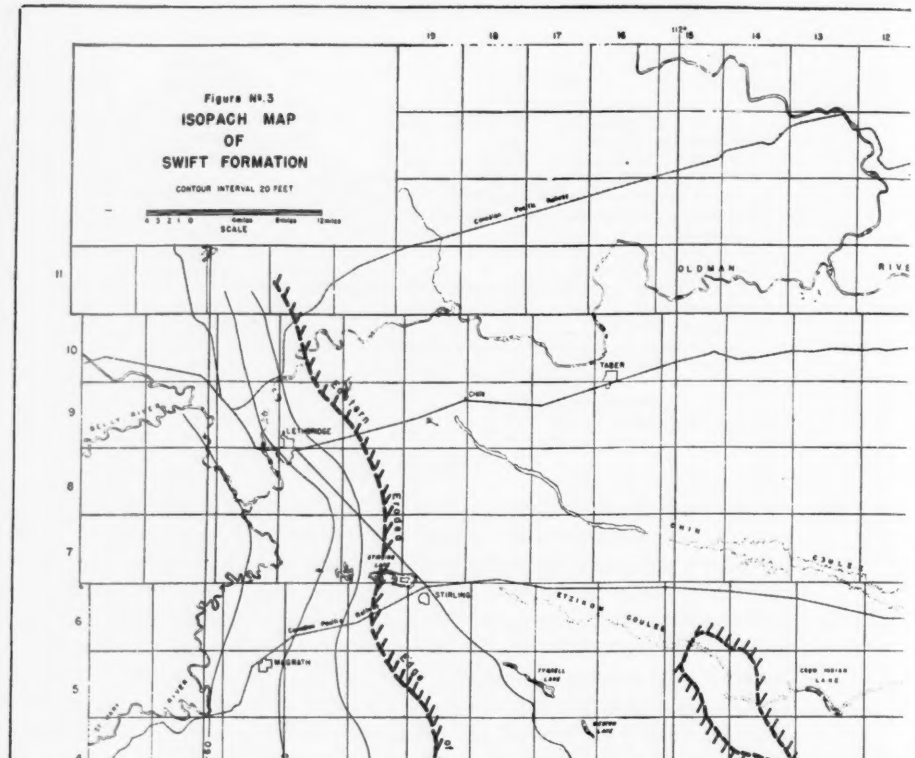
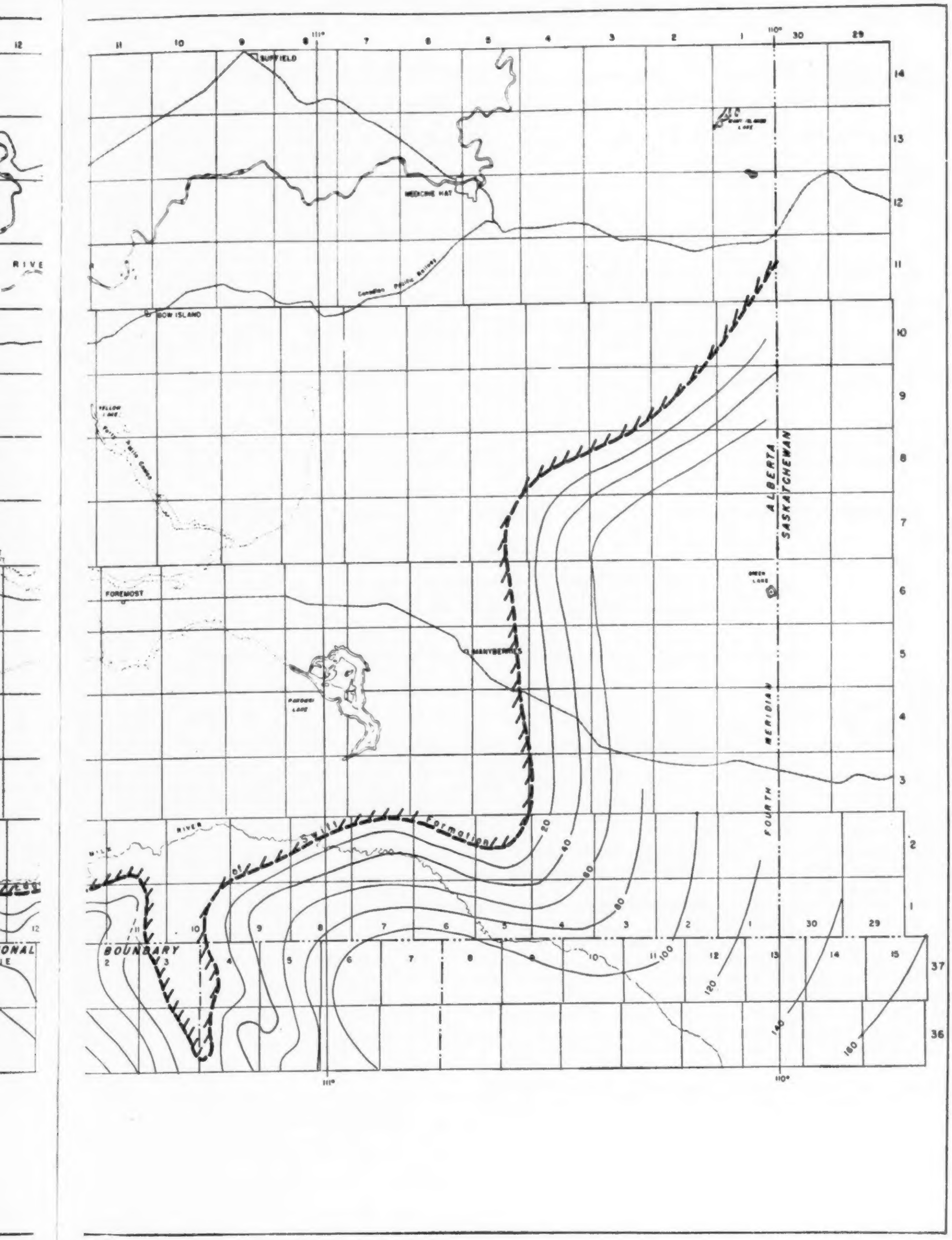


FIG. 3.—Isopach map of S



map

of Swift formation.

McColl-Frontenac 6-8-1-8	Lsd. 6, Sec. 8, T. 1, R. 8, W. 4th Mer.
California Standard	
Crow Indian Lake Province No. 2	SE. ¼ of Lsd. 1, Sec. 20, T. 4, R. 14, W. 4th Mer.
Conrad Province No. 75-36-C	SE. ¼ of Lsd. 12, Sec. 36, T. 4, R. 15, W. 4th Mer.
Conrad Province No. 55-21-B	SE. ¼ of Lsd. 11, Sec. 21, T. 5, R. 15, W. 4th Mer.
Conrad Province No. 2	SE. ¼ of Lsd. 1, Sec. 5, T. 6, R. 15, W. 4th Mer.

In addition, traces of chert pebbles have been recognized from this horizon in cuttings from McDougall-Segur McLeod's Comrey No. 1 in Lsd. 5 of Sec. 9, T. 1, R. 5, W. 4th Mer. and Commonwealth Milk River No. 1 in Lsd. 8 of Sec. 9, T. 3, R. 15, W. 4th Mer.

The glauconite zone at the contact is recognizable at the following localities.

Rialto No. 1	Lsd. 4 of Sec. 15, T. 1, R. 9, W. 4th Mer.
Urban Oils Ltd. No. 1	Lsd. 2 of Sec. 4, T. 1, R. 15, W. 4th Mer.
Sunshine Oils Ltd. No. 1	Lsd. 10 of Sec. 19, T. 1, R. 21, W. 4th Mer.

A completely cored section of the Swift formation showing both members follows.

McColl-Frontenac's 6-8-1-8

Center of Lsd. 6, Sec. 8, T. 1, R. 8, W. 4th Mer.

	Depth (Feet-Inches)		*Thickness (Feet-Inches)*	
Blairmore formation				
Unconformity				
Swift formation				
Sandstone, pale gray, very fine-grained, quartzose, with pale green glauconite(?) giving faint green cast to sand, abundant muscovite mica. Sand is wavily cross-bedded with pale gray, very micaceous shale	2,949–2,951		2	
Sandstone as above, interbedded shale becoming pale brown with abundant muscovite mica	–2,956		5	
Sandstone as above, white, quartzose, very fine-grained, very glauconitic, wavily interbedded with dark brown micaceous shale	–2,970		14	
"Ribbon type" sandstone as above, some thin beds of sand are fine-grained "salt and pepper"	–2,986		16	
Sandstone, pale gray, fine-grained to medium-grained, "salt and pepper," quartz grains showing crystal faces, chert about 20–30%, intergranular porosity good, a few paper-thin partings of dark brown, micaceous shale	–2,998		12	
Shale, dark brown, micaceous, with paper-thin partings of fine, micaceous, glauconitic quartzose sand	–3,000		2	
Shale, medium gray, micaceous, with a few thin beds of quartzose sand	–3,000	6	10	6
Shale, dark gray, extremely glauconitic, with rolled pellets of dark gray, non-glauconitic shale and black chert pebbles	–3,012		1	6
Thickness of Swift formation			63	
Disconformity				
Rierdon formation				

A cored section of the Swift formation showing the basal shale follows.

CALIFORNIA STANDARD COMPANY'S CONRAD PROVINCE NO. 2

SE. ¼ of Lsd. 1, Sec. 5, T. 6, R. 15, W. 4th Mer.

	Depth (Feet-Inches)		*Thickness (Feet-Inches)*	
Blairmore formation				
Shale, black, coaly, with pyrite nodules	2,836–2,836	2		2
Shale, dark brownish gray, bentonitic, slightly carbonaceous, pyritic	2,838	4	2	2
Siltstone, or very fine-grained sandstone, greenish at top grading down into gray, hard, calcareous, a few pyrite nodules. At base is 1-inch bed of dark brownish gray, silty shale on ½-inch bed of shaly sandstone containing band of pyrite nodules. One small chert pebble near bottom	–2,854		15	8
Uncomformity				
Swift formation				
Shale, dark brown, silty, micaceous, finely pyritic. Bottom 6 inches extremely glauconitic, one chert pebble observed	–2,858		4	
Thickness of Swift formation			4	
Disconformity				
Rierdon formation				
Shale, pale green, slightly pyritic, non-glauconitic	–2,860		2	
Shale, dark green, finely pyritic, one limy shale band and one 2-inch bed of blue bentonite. Shale contains minute pelecypods and one large fossil fragment (*Gryphea?*)	–2,868		8	
Base of cored section				

CONTINENTAL DEPOSITS OVERLYING ELLIS GROUP

A variable series of continental beds overlies the Ellis group in Southern Alberta. These beds are all referred to the Lower Cretaceous (Blairmore formation of Canada, Kootenai formation of Montana) by the writer. It is believed that no beds of Morrison age reach Southern Alberta in the area of the Sweetgrass arch, having been removed by post-Morrison—pre-Blairmore erosion. The upper, and by far the greater part of the Blairmore formation, consists of dull green and dull maroon mudstones, drab gray shales and silts, alternating with lenticular beds of "salt-and-pepper" sandstones containing quartz and dark chert grains with much clay cement, brown siderite concretionary grains, and plant remains. A few coal seams occur in the Blairmore, some of which have been used locally as markers in the formation. There is a general decrease in the proportion of red colors northward.

At the base of the Blairmore a separate unit may be recognized in a general way. It consists of pale buff to putty-colored, light gray, light lavender, and light green bentonitic mudstones containing scattered sand grains which are predominantly quartz but contain red and amber chalcedony grains. Lenticular shaly quartzose sandstones occur in this zone. Near the top of the zone in many localities of Southern Alberta are pale buff lithographic fresh-water limestones or marls. This zone is called the Sunburst zone in Alberta and it is believed that

it can be traced into the Sunburst zone of Montana. The magnetite sand at the top of the zone has not been recognized in Alberta. The zone is not everywhere characteristically developed.

Beneath the Sunburst zone in some areas are coarse, cherty, "salt-and-pepper" sands lithologically similar to the Cutbank sand of Cutbank field, Montana. Where present in Southern Alberta these basal Cutbank-type sands rest directly on the Rierdon formation. In the east Taber field shales immediately above these basal Cutbank-type sands have yielded a flora from which the following species have been identified by W. A. Bell[13] of the Canadian Geological Survey: *Cladophlebis oerstedi* (Heer), *Sequoia condita* Lesquereux, *Sphenopteris* sp., *Sphenopteris* (*Adiantum?*) *montanense* (Knowlton), *Athrotaxites ungeri* Halle, and *Elatides curvifolia* (Dunker). This flora has been dated by Bell as definitely Aptian in age. Cobban has suggested that the fresh-water limestones at the top of the Sunburst zone in Montana contain an Aptian fauna. Thus, the correlation of the Sunburst zone and Cutbank sand from Montana into Alberta on lithological grounds is supported by fossil evidence.

The unconformity between the Lower Cretaceous and the Ellis group is of considerable magnitude regionally. In the south, Lower Cretaceous beds rest on the highest member of the Swift formation, while farther northward they rest on the lowest beds of the Rierdon and, where it is present, on the Sawtooth formation. The local relief on the surface of the Ellis is, however, generally slight but has an influence on the distribution of the basal beds of the Lower Cretaceous.

GEOLOGICAL HISTORY

The history of Jurassic deposition in Alberta is not so well known as in Montana due to removal by pre-Blairmore erosion of much of the evidence. The upper Bathonian transgression of the Sawtooth sea described by Cobban in Montana extended north into Alberta. East of the Sweetgrass arch the sea flooded in from the east and southeast across a low limestone land with local topographic relief, first filling the valleys and later transgressing the ridges. By the end of the Bathonian some islands still remained above the sea. The northern shore lines of this sea presumably were north of the present extent of the Sawtooth formation. West of the Sweetgrass arch not enough evidence has yet been collected in Canada to detail the stages of transgression during the Bathonian.

During the Callovian stage the sea extended across all of Southern Alberta from the Rocky Mountain geosyncline in the west to Saskatchewan in the east. The uniform nature of the calcareous shales and thin limestones over this large area indicates quiet-water deposition and low shore lines. No shore phases of the Rierdon have been recognized and the northern shore of the Callovian sea must have been a considerable distance north of the present extent of the Rierdon formation which has been determined by pre-Blairmore erosion.

[13] W. A. Bell, personal communication.

The early Divesian regression of the sea was followed by a later Divesian transgression and both occurred in Southern Alberta as in Montana but little more can be added. It seems probable that following the retreat of marine waters from the area some continental Jurassic (Morrison) deposition took place as in Montana.

At some time later than the Divesian and probably later than the Kimmeridgian, active erosion of the Jurassic beds commenced. All of the Morrison formation was removed from the Southern Alberta Plains. The Swift formation was removed excepting in a narrow belt in the southeast, the southwest, and the extreme south. The Rierdon was bevelled from its maximum thickness of 140 feet in the south to zero in the north. The present extent of the Jurassic formations could be explained as the effect of truncation by a north-sloping topographic surface such as a broad valley widening northward. Slight warping over a broad north-south arch tilted slightly southward may also be indicated.

CONCLUSIONS

The three-fold division of the Ellis group established by Cobban in Montana can be recognized in Alberta.

The Sawtooth formation is represented by an upper sandstone, a medial shale member, and a lower sandstone member. These units interfinger eastward with limestone, shale, and sandstone beds. The top of the Sawtooth formation is marked by widespread shaly conglomerate with belemnites and chert pebbles.

The Rierdon formation is represented by typical greenish gray, calcareous shales and argillaceous limestones as in Montana.

The Swift formation consists of a lower dark gray, non-calcareous micaceous shale and an upper thin-bedded "Ribbon" sand member. Glauconite and chert pebbles at the contact of the Swift and underlying Rierdon have been found in many places in Alberta.

The Jurassic formations have been truncated by post-Jurassic pre-Blairmore erosion. They thin from south to north. The overlying Blairmore formation rests on Ribbon sands in the south, on the shale member of the Swift at Conrad, on Rierdon shales over most of the Southern Alberta Plains, and directly on the Paleozoic north of the Oldman River.

The continuity of the marine Jurassic formations in Southern Alberta with the formations established by Cobban in Montana is indicated by subsurface correlation. The use of the formational names Sawtooth, Rierdon, and Swift in Alberta appears justified. The formations are too restricted in Alberta because of pre-Blairmore erosion to warrant giving Canadian names.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 4 (APRIL, 1949), PP. 564-571, 1 FIG.

FOSSIL ZONES OF DEVONIAN OF ALBERTA[1]

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ABSTRACT

Devonian strata are known to underlie the greater part of the Great Plains region of Alberta, though generally covered by a thick succession of later rocks. The Devonian rocks are exposed along the fringes of the Plains area where the later rocks have been eroded or where orogenic movements have brought them to the surface. The exposed Devonian rocks have been studied for index fossils which will be helpful in elucidating the various formations penetrated in the Plains area by oil-well operations.

The following zones are suggested for the Upper Devonian in descending order: (a) *Tornoceras*, (b) *Cyrtospirifer*, (c) Coral, (d) *Spirifer jasperensis* (divided into two subzones), and (e) Stromatoporoid zone.

Apparently the Middle Devonian is not widely spread under the Great Plains. It appears to be accompanied by salt-bearing beds in many places. A few genera and species are suggested for diagnostic purposes, such as *Stringocephalus*, *Atrypa* of different species, and *Martiniopsis*.

INTRODUCTION

Devonian rocks appear to underlie most of the Great Plains area of Canada. Throughout most of this area the Devonian strata are overlain by a thick mantle of Mesozoic and, in places, Tertiary rocks. On the northeast flank of the Plains area Devonian strata are exposed through erosion of the overlying Mesozoic rocks, and on the western flank Devonian rocks are exposed in the great fault blocks of the Rocky Mountains. In the intervening area the Devonian is encountered only by deep drilling. The Devonian rocks exposed along the fringes of the Plains area have been studied in sufficient detail to obtain a knowledge of the main fossil zones which provide a ready means of establishing, with considerable precision, the age of the Devonian rocks pierced by the drill in the areas covered by later strata. This paper reports on the zones useful in age determination and correlation in the Plains area.

AGE OF DEVONIAN ROCKS EXPOSED ON FRINGES OF CANADIAN PLAINS

MANITOBA PLAINS

In Manitoba, Devonian rocks overlying Silurian and Ordovician strata crop out in a narrow strip striking northwestward. They are overlain on the west by rocks of Mesozoic age. The Devonian strata comprise a thin series of limestones and dolomites at least 300 feet thick and represent the upper part of the Middle Devonian (5). Three formations are represented (in ascending order): Elm Point limestone, Winnipegosan dolomite, and Manitoba limestone. An erosional unconformity occurs at the top of this succession as it is overlain by Mesozoic rocks. It is evident, therefore, that the uppermost Devonian rocks may not be the same age in all localities and Upper Devonian rocks may be present in some areas.

[1] Read before the Alberta Society of Petroleum Geologists, November 27, 1947. Manuscript received, February 12, 1948.

[2] Professor of paleontology, University of Alberta.

At approximately 54° Latitude, the strike of the Paleozoic rocks swings toward the west and Cretaceous rocks overlap on pre-Cambrian rocks. Where Devonian rocks re-appear north of this overlap, no Middle Devonian has been observed, but rocks of Upper Devonian age are present and continue to strike northwestward along the edge of the Shield. These rocks have been studied in the vicinity of McMurray on Athabaska River (12).

ATHABASKA RIVER

At McMurray, Latitude approximately 57°, Devonian limestones crop out along the Athabaska River. Only the top of the Devonian section is exposed, but drilling has demonstrated a total thickness of 405 feet (1), the lower of which is shale. The whole section has been named the Waterways formation (12) and is considered to represent the lower part of the Upper Devonian. The Waterways formation lies directly on a succession of dolomites, gypsum, and salt which is usually considered to be Silurian in age. It is overlain by Cretaceous strata.

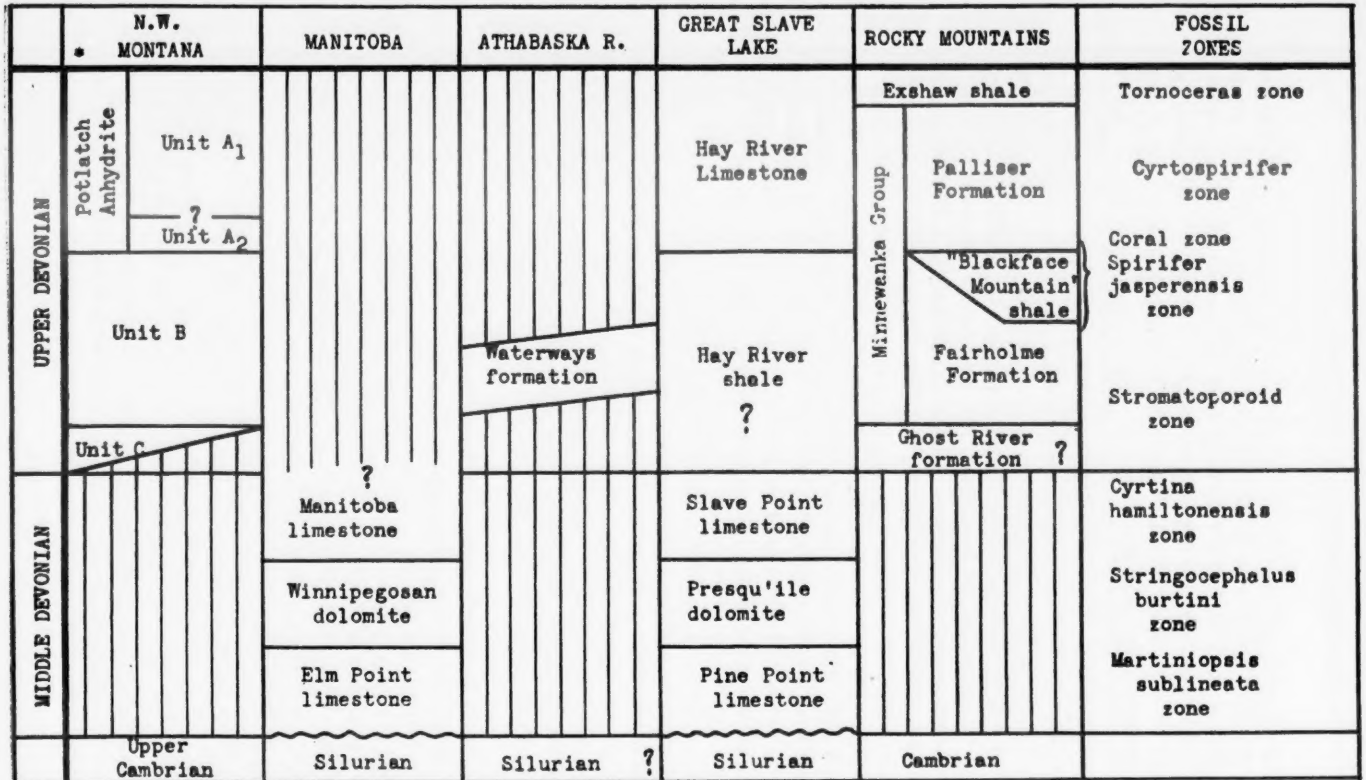
Exposures of Waterways formation continue down the Athabaska River to Lake Athabaska. The same formation is also exposed at Peace Point on the Peace River, just west of Lake Athabaska, where it is observed overlying Silurian dolomites with gypsum. Farther west on the Peace River, at Vermilion, younger Devonian rock of the Hay River limestone appears in the section.

VICINITY OF GREAT SLAVE LAKE

Along the shores of the western part of Great Slave Lake, Middle Devonian rocks again appear in a rather thick section (3). They overlie Silurian rocks containing gypsum and are overlain on the west by a thick section of Upper Devonian rocks exposed largely on rivers flowing from the west into Great Slave Lake and the Mackenzie River. The Upper Devonian is overlain by Cretaceous rocks. The section of rocks along the Lower Mackenzie is not considered in this paper.

The Middle Devonian section at Great Slave Lake and vicinity has been subdivided into the following formations: Pine Point limestone, overlain by the Presqu'ile dolomite and the Slave Point limestone. This section is 1,170 feet thick. It is rather closely correlative in type of rock and faunal content with the Middle Devonian section in Manitoba, the main distinction being the greatly increased thickness of the Great Slave formations. The Manitoba Devonian section is undoubtedly a foreland deposit, whereas the Great Slave section more closely resembles deposition in a geosyncline.

The Upper Devonian as developed west of Great Slave Lake consists of a thick series of calcareous shale, the Hay River shale, and is overlain by thick limestones known as the Hay River limestone. The complete section on Hay River is 950 feet thick (3). A shale bed is commonly present in the Hay River limestone, dividing that formation into an upper and a lower part. The Hay River shale may be correlated, in part, with the Waterways formation at McMurray on the Athabaska River (12). As the Hay River limestone is separated from the



* Sloss and Laird (13)

Correlation of Devonian Strata in Western Canada and Northwestern Montana — Figure 1

FIG. 1

overlying Cretaceous strata by an erosional unconformity of considerable magnitude, it may be taken for granted that the thickness of the Upper Devonian section varies greatly in different localities.

ROCKY MOUNTAINS

Devonian strata in the Rocky Mountains are a thick series of limestones and dolomites and shale which are more than 3,000 feet thick in the vicinity of Banff, Alberta (11). The name Minnewanka formation has been used as a covering name for the whole sequence. Local names have been applied to various parts of the Minnewanka in different places. A black non-calcareous shale, approximately 35 feet thick, at the top of the Devonian sequence has been named the Exshaw formation (13). The upper, more massive part of the sequence of dolomites and limestones has been named the Palliser formation, and the lower, thinner-bedded, more variable part of the sequence, the Fairholme formation (2). These names are applicable in the area around Banff. South and north of Banff a bed of black shale appears in the section corresponding in position with the upper beds of the Fairholme formation. Farther north at Mountain Park and Jasper, a second shale bed appears, apparently corresponding in position with beds in the lower part of the Palliser formation. The two shale beds are separated by thin beds of rubbly limestone. The two shale beds, together with the intermediate limestones, have been termed the Blackface Mountain shale (4). On Roche Miette, at Jasper, the lower shale bed was termed the Perdrix shale by Raymond (8), and the Miette shale by Kindle (6). The term "Blackface Mountain" has been used rather widely by the writer for the lower shale only. Such usage is followed in this paper. It should be kept in mind, however, that this shale bed may not occur at exactly the same horizon in all localities and that it varies considerably in thickness. The age of the Minnewanka is Upper Devonian.

MONTANA

The best known Devonian section in Montana, that in the vicinity of Three Forks, comprises two formations, the Jefferson limestone below and the Three Forks shale above. The Three Forks shale, which may be as much as 280 feet thick, corresponds with the upper part of the Palliser formation and the Exshaw shale of the Banff section, and the Jefferson with the lower part of the Palliser and the Fairholme formation. The Jefferson varies considerably in thickness, averaging approximately 600 feet. In the area of the Kevin-Sunburst field, a bed of anhydrite, 250–350 feet thick, was found to overlie the Jefferson limestone and is known as the Potlatch anhydrite. It was believed to be a correlative of the Three Forks shale (9), but more recent work by Sloss and Laird (10) has shown that this evaporite also represents the upper part of the Jefferson. The Potlatch evaporite is widely dispersed under the Plains area in Alberta where it is commonly overlain by a thin section of upper Minnewanka limestone. The age of the Three Forks and Jefferson formations is Upper Devonian.

FOSSIL ZONES IN UPPER DEVONIAN

The Upper Devonian fossil zones of the Alberta sequence are best known in the Rocky Mountains. They may be listed in descending order, as follows.

Tornoceras zone
Cyrtospirifer zone
Coral zone
Spirifer jasperensis zone
Stromatoporoid zone

These zones are present in most sections of the Minnewanka formation in the mountains and may be detected in most well logs in the Plains area where the whole Upper Devonian sequence is present.

TORNOCERAS ZONE

The *Tornoceras* zone is restricted to the Exshaw shale at the top of the Devonian sequence. This thin shale zone is easily detected by its black color and non-calcareous character, even where fossils are not present. In some sections in the mountains the shale contains a considerable abundance of *Tornoceras* cf. *T. uniangulare* (Conrad) and some poorly preserved pelecypods. *Tornoceras* has been observed in several well logs in the Plains area and in some places accompanied by conodonts.

In the calcareous beds overlying the Exshaw shale, *Spirifer marionensis* Shumard has been detected in well logs. This species is not easily identified where poorly preserved because it resembles *Spirifer centronatus* Winchell. The *S. marionensis* fauna is usually considered basal Mississippian, but some geologists believe that it represents the uppermost Devonian. In this paper it is not included in the Devonian section.

CYRTOSPIRIFER ZONE

The *Cyrtospirifer* zone includes the upper 600–800 feet of the Minnewanka limestone. The strata are commonly limestone but in some sections they are dolomitized, excepting for the uppermost beds. The dolomitization has ordinarily destroyed the fossils, and the zone fossils obtainable are confined to the limestone beds at the top. The most abundant fossils are *Productella coloradoensis* Kindle, *Camarotoechia horsfordi* Hall, *Camarotoechia nordeggi* Kindle, *Leiorhynchus*, several species, *Cyrtospirifer* of the *C. whitneyi* type, and *Athyris angelica* Hall.

In this thick zone the species are not equally distributed and more intensive study may show the presence of two sub-zones, an upper sub-zone with *Camarotoechia nordeggi* and *Athyris angelica* especially abundant, and a lower sub-zone with *leiorhynchids* more abundant. The various species and varieties of the genus *Cyrtospirifer* may also show zonal value.

So far as the writer's limited observations are concerned, the Potlatch evaporite occurs in the lower part of the *Cyrtospirifer* zone. The typical *Cyrtospirifer* fauna has not yet been observed below the anhydrite.

CORAL ZONE

The coral zone is not everywhere identified in the Minnewanka formation but corals occur in a few sections. If the beds below the *Cyrtospirifer* zone are thin-bedded or shaly, as in some sections, corals are not abundant, and if the same zone is dolomitized, the corals are not identifiable. Nevertheless, the zone is worth consideration and it has been spotted in well logs.

The most abundant corals so far obtained in this zone are "*Diphyphyllum*" *colemanse* Warren, *Cladopora* sp., and poorly preserved *Phillipsastrea*. These corals probably extend into the *Cyrtospirifer* zone above and are known to extend into the *Spirifer jasperensis* zone below. The zone may be correlated, in part, with the basal bed of the Hay River limestone of the upper Mackenzie valley section.

SPIRIFER JASPERENSIS ZONE

Most of the lower half of the Minnewanka limestone is contained in the *Spirifer jasperensis* zone. This zone does not extend to the lower beds of the Minnewanka section and the contained fauna is apt to be found in the lower beds of the coral zone. In most sections in the mountains, a thick shale bed occurs in the middle of the zone, the "Blackface Mountain" shale, which is commonly nonfossiliferous, and thus destroys the continuity of the fauna of the zone.

The zone has yielded a considerable fauna besides the zone marker, *Spirifer jasperensis* Warren. The most abundant species are *Cladopora* sp., "*Diphyphyllum*" *colemanse* Warren, *Lingula spatulata* Vanuxem, *Chonetes deflecta* Hall, *Productella hallana* Walcott, *Schizophoria striatula* Schlotheim, *Leiorhynchus athabaskense* Kindle, *L. albertense* Warren, *Pugnax* sp., *Spirifer raymondi* Haynes, *Martinia nevadensis* Walcott, *Atrypa*, many species, *Cyrtina rockymontana* Warren, *Bactrites aciculum* Hall, *Goniatites* of the *Manticoceras* type, *Buchiola retrostriata* von Buch, and *Entomis serratostriata* Sandberger. This is an Upper Devonian fauna of about Naples age.

The "Blackface Mountain" shale divides this fauna into two divisions or sub-faunas which are differentiated more by the abundance of certain species than by difference in species alone. The upper sub-zone is notable for the abundance of various species of *Atrypa* and *Schizophoria*, *Leiorhynchus albertensis*, *Cyrtina rockymontana*, *Productella hallana*, and *Chonetes deflecta*. At the top of the sub-zone, corals may become abundant. The species *Spirifer jasperensis* is rare in this sub-zone, and its place is taken by *Spirifer raymondi* Haynes which has sometimes been listed as *Spirifer mucronatus* Conrad.

This sub-zone marks the acme of development of the genus *Atrypa* in the Minnewanka formation and with species of the genus *Schizophoria* it makes up a large percentage of the total collections from the sub-zone. *Atrypa* declines in importance above this horizon and to the writer's knowledge has not been collected in the upper part of the *Cyrtospirifer* zone. This sub-zone is probably correlative with part of the Waterways formation at McMurray.

The fauna below the "Blackface Mountain" shale has an abundance of

Spirifer jasperensis, an undescribed species of *Leiorhynchus*, *Productella hallana*, species of *Martinia* including *M. nevadensis* Walcott, *Buchiola retrostriata*, and *Entomis serratostriata*. *Atrypa* is present but not abundant.

The fauna is not identifiable if the beds are dolomitic, which is commonly the case, but it can be identified ordinarily in well logs in the Plains area, largely through the presence of the *Buchiola* and *Entomis serratostriata*.

STROMATOPOROID ZONE

The beds near the base of the Minnewanka are ordinarily dolomitic and lack identifiable fossils. Stromatoporoids occurring in thick beds or reefs are present and are conspicuous on the weathered surface. The finer structure in the stromatoporoids is commonly destroyed, which precludes positive identification of genus or species. Stromatoporoids have been observed at other horizons but nowhere in such abundance as in this lower zone. The stromatoporoid zone has been identified in samples and cores of wells in the Plains area.

FOSSIL ZONES OF MIDDLE DEVONIAN

The Middle Devonian is exposed on the Red River plain of Manitoba and on Great Slave Lake. The strata appear to be of approximately the same age in both areas, but the section at Great Slave Lake is very much thicker than that of Manitoba and is more in the nature of a geosynclinal deposit. In both areas the *Stringocephalus* zone is present with a considerable thickness of rocks both above and below it. There must have been a connection between the two areas because *Stringocephalus* is present in both. No evidence of this connection is seen in exposures below the Cretaceous along the margin of the plain in the Athabaska River area where Upper Devonian strata lie directly on pre-Cambrian or Silurian rocks. The connection must have been farther west under the Plains area, but there is little evidence, excepting in one well near Unity, Saskatchewan, that Middle Devonian rocks are present below the Upper Devonian strata.

The faunas of the Middle Devonian and their vertical range through the strata are not so well known as those of the Upper Devonian. The reason for this is probably the lack of Middle Devonian rocks in at least the southern part of the Canadian Rockies. Nevertheless, the fauna is distinctive from that of the Upper Devonian but the differences are not so readily detected in well logs.

From the writer's experience, the most common fossils collected in outcrops of Middle Devonian are species of *Atrypa* and this genus may well be the most useful in distinguishing the faunas. So far as known, no species of *Atrypa* is common to both Middle and Upper Devonian, but the difference between the species is drawn on rather fine lines and it would require considerable experience to use the genus as an horizon-marker. However, it will be useful to the expert. The large shells of *Stringocephalus burtini* Defrance probably would not be recognized in small well cores and the smooth shells of *Rensselandia* which occurs at approximately the same horizon may also be difficult to determine. The sponge

Sphaerospongia tesselata (Phillips), from the *Stringocephalus* zone, would be of much greater value as this species could be determined even in a fragmentary condition. The genus *Favosites* is an excellent horizon-marker for the Middle Devonian in this area as the genus has not been reported from the Upper Devonian rocks of the Mackenzie valley. The smooth-shelled brachiopod *Martiniopsis* is prevalent in the Middle Devonian rocks of this area and especially in the basal beds. In the Pine Point limestone of Great Slave Lake, *Martiniopsis sublineata* (Meek) is the most abundant species collected, and may well be used as the zone fossil for the lowest horizon of the Middle Devonian in the northern area. It is small and ordinarily well preserved and should be recognized easily in a well core. The zone of *Martiniopsis sublineata* probably is correlative with the *Martinia kirki* zone of Merriam in the Roberts Mountain section in Nevada (7).

In the formations above the *Stringocephalus* zone, the species *Cyrtina hamiltonensis* Hall and *Hypothyridina cameroni* Warren are probably the most distinctive and the most easily recognized forms. They appear to be rather scarce, however, which would lessen their value as zone fossils, especially in well logs.

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LEDUC OIL FIELD, ALBERTA, A DEVONIAN CORAL-REEF DISCOVERY[1]

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ABSTRACT

The Leduc oil field, a major discovery in 1947, is near the center of the province of Alberta, Canada. The discovery well, completed in February, 1947, was located on the basis of reconnaissance seismic work by a Carter Oil Company crew and detail by a Heiland Exploration Company crew working for Imperial Oil Limited. By February 1, 1948, 37 flowing wells were producing 4,470 barrels of oil a day under Government allowables. The extent of the field has not been defined, but a probable area of at least 8,100 acres, with an estimated recoverable reserve well in excess of 100,000,000 barrels, is indicated.

With the exception of exposures of Upper Cretaceous continental beds along stream channels, the entire area is covered with glacial drift. In the stratigraphic section drilled to date in the field only two periods, the Cretaceous and Devonian, are represented.

The main producing zones are Upper Devonian dolomites, and are temporarily called the D-2 and D-3 zones. These occur at depths of 4,850–5,400 feet, or 500–900 feet below the top of the Devonian. The D-3 zone, from both its innate characteristics and its regional aspects, appears to be a coral reef. The D-2 zone is rich in coralline material but is a blanket-type deposit. It has an almost constant thickness but a variable porosity throughout a broad regional area. Development of the field is too incomplete to permit a clarification of the structural picture, but the accumulation appears to be due to both stratigraphic- and structural-trap conditions. Development is proceeding rapidly, and, as of February, 1948, 1 year after discovery, 20 rigs were in operation. Spacing is set by the Provincial Government at 40 acres per well, with twin wells being drilled in each 40-acre tract where both zones are productive.

INTRODUCTION

LOCATION

The Leduc field, discovered in February, 1947, is in the province of Alberta, at Latitude 53° 15′ N. and Longitude 113° 45′ W. The proved and semi-proved area, as of February, 1948, extends 7½ miles north and south and 5 miles east and west. It is 15 miles southwest of Edmonton, the capital of Alberta, and is 160 miles north of Calgary, the second largest city in the province (Fig. 1). The field is south of the center of Alberta, being 450 miles from the northern boundary and 300 miles from the International border. The Rocky Mountains are 160 miles west and the pre-Cambrian shield 300 miles northeast.

The topography in the Leduc field has very little relief excepting in the central part, where the North Saskatchewan River has cut a valley 200 feet deep. The

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Those contributing geological data for the report were E. W. Shaw, western Canada division geologist, Calgary; W. P. Hancock, head of subsurface department, Calgary; S. R. L. Harding, staff geologist, Calgary; and J. B. Newland, subsurface geologist, Calgary. Development and related subjects were prepared by R. Pot, reservoir engineer, and M. P. Paulson, district petroleum engineer, under the supervision of J. D. Gustafson, division petroleum engineer. The report was prepared under the supervision of J. B. Webb, exploration manager, Calgary. Constructive criticisms and suggestions were made by T. A. Link, formerly chief geologist, and W. D. C. McKenzie, chief petroleum engineer, Imperial Oil Limited, Toronto, Ontario. The geophysical work was under supervision of R. A. Walters division geophysicist, Calgary.

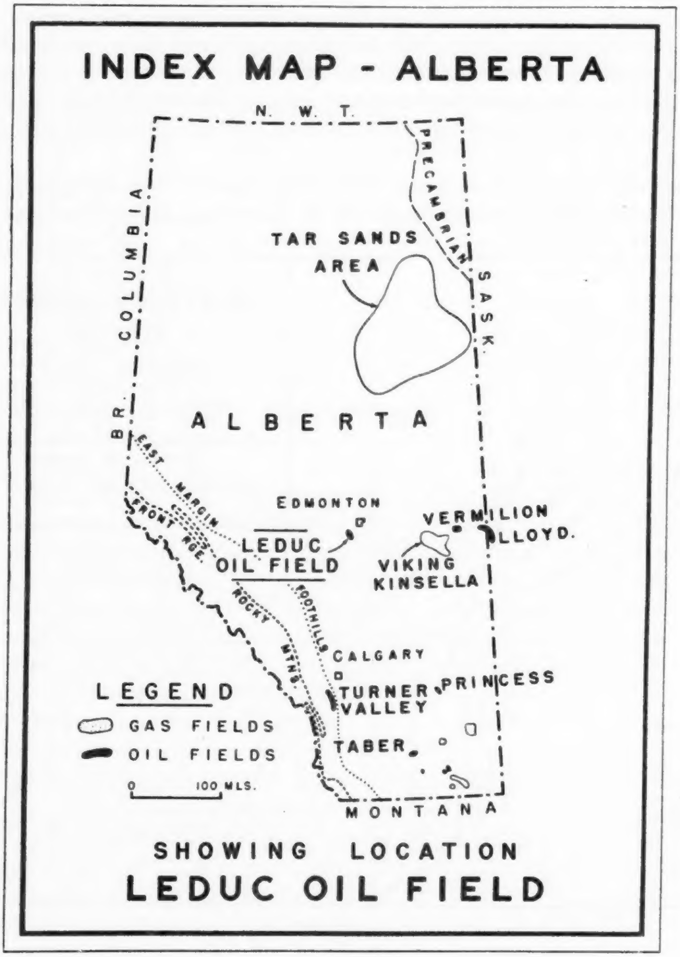


Fig. 1

average elevation of the ground surface is 2,350 feet above sea-level. The field is in the "Park Lands" area north of the semi-desert areas typical of southern and southeastern Alberta, and is south and east of the "muskeg country" characteristic of much of the northern part of the province.

REGIONAL GEOLOGICAL SETTING

The Leduc area is in the extensive Western Canada sedimentary basin, which stretches across Manitoba, Saskatchewan, and Alberta, a distance of 750 miles,

and northward to the Arctic Ocean. The detailed structure and stratigraphy of this tremendous basin area, which is a continuation of those extending from North Dakota and Wyoming, are little known as yet. However, the area has been subdivided into various major structural features, shown in Figure 2. The Leduc oil field is in the westward-dipping homoclinal belt of central and northeastern Alberta.[3]

The beds dip gently from Leduc to the foothills structures. Here, large thrust faults have brought early Mesozoic beds to the surface; still farther west, great

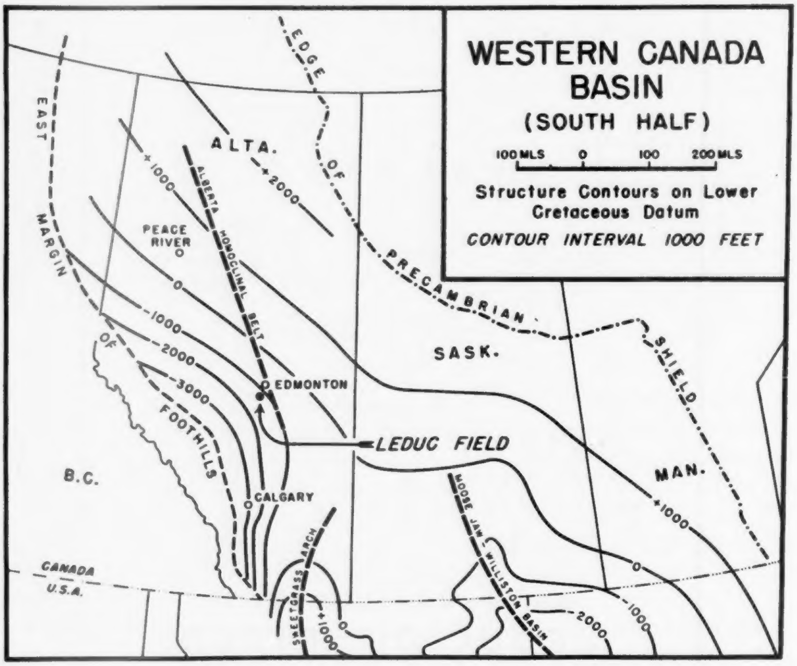


FIG. 2

fault blocks forming the Rocky Mountains expose Paleozoic and Proterozoic sediments which have been thrust to present elevations as high as 12,000 feet above sea-level. East and north of Leduc, to the pre-Cambrian shield, the beds rise gradually, ordinarily less than 20 feet a mile, and progressively older beds are exposed. A similar, gradual rise is apparent southeastward, but near the Alberta-Saskatchewan boundary the beds dip gently into the Moose Jaw syncline, the northern extension of the Williston basin of North Dakota.

[3] *Possible Future Oil Provinces of the United States and Canada*, Amer. Assoc. Petrol. Geol. (1941).

Figure 2, showing the present basin configuration on top of the Lower Cretaceous beds, is a highly generalized picture based on extremely little information. This basin structure will probably be proved to be composed of subsidiary basins which have had a major influence on petroleum accumulation.

HISTORY OF DISCOVERY

The Imperial's Leduc 1, spudded on November 20, 1946, was a venture into unknown territory. Within a radius of 60 miles of this discovery well, only eight wells had been drilled, and of these only two reached Paleozoic beds. The remaining six wells had been drilled much earlier and well cuttings and other information were either unreliable or missing entirely.

In spite of this lack of information regarding the area, the possibility of oil or gas accumulation in Lower Cretaceous and Paleozoic beds had been postulated from regional structural and stratigraphic information. The Imperial Oil Limited therefore decided to drill a stratigraphic well to test the economic possibilities in all beds down to and including the Cambrian in the Edmonton area. To make a more precise location, a reconnaissance seismic survey was made of a large area under reservation from the Provincial Government. The reconnaissance uncovered a few anomalies, including one slightly south and west of Edmonton and 8 miles west of the village of Leduc. A more detailed coverage was obtained, and on the basis of this a location for the initial test was chosen.

Well No. 1 was located near the indicated center of the structure, and drilling began on November 20. Provincial Government regulations stipulate that samples of well cuttings be collected at least every 10 feet, but at this wildcat samples were taken at 5-foot intervals to obtain the maximum amount of information. Furthermore, the hole was cored continuously from above the Viking sand into the top of the Devonian, a 940-foot interval.

At the depth of 3,534 feet the well reached the first prospective zone, the Viking member, composed of interbedded sand and shales in the lower part of the Colorado. As this zone contains large reserves of dry gas in the Viking-Kinsella field (Fig. 1) 75 miles east, company geologists decided that detailed testing was warranted. A drill-stem test showed a very small flow of gas and 225 feet of gasified salt water. Coring was continued and 350 feet deeper in nonmarine Lower Cretaceous beds the drill encountered a sand saturated with low-gravity oil, which gave negative results on a drill-stem test. At 4,246 feet, still in Lower Cretaceous beds, well sorted quartz sand, tested in short intervals, produced a substantial wet-gas flow and a showing of 30° A.P.I. oil, but contained salt water in the basal part. Prospects seemed brighter and coring was continued to the base of the Lower Cretaceous beds at 4,390 feet. Here the bit entered Upper Devonian dolomites and limestones. After drilling 25 feet of dense, dolomitic, fractured limestone, porous, oil-stained dolomite was encountered. Drill-stem tests showed a favorable gas accumulation with some naphtha and traces of salt water. Drilling and intermittent coring were continued through inter-

bedded, porous and dense dolomites and dolomitic limestones to 4,800 feet where bedded anhydrite was encountered. At 4,955 feet a section of red and green mottled siltstone was entered and at 4,995 feet dolomite, stained with light oil, was reported. Then began the process of coring, testing, and coring a little deeper, each test becoming more favorable: first, a small wet gas flow, then a second test showed a rise of 840 feet of crude oil; finally, on February 1, 1947, with the bottom of the hole at 5,049 feet, oil flowed to the surface. After further testing, the well was completed to the depth of 5,066 feet, and a production string of 7-inch casing was run and cemented at 5,029 feet. On February 13, the well was swabbed in, and the first crude oil from the Leduc field began to flow into tanks at the flush rate of 1,000 barrels a day.

Meanwhile, in the hope of encountering oil downdip in the Lower Cretaceous sand, the Imperial Oil had located well No. 2, 1½ miles south and slightly west of No. 1. Water was encountered in the Lower Cretaceous gas sands above the Devonian in well No. 2, but hope was still high. A test in the upper 100 feet of the Devonian section, resulted in a 1,000 foot rise in the drill-pipe of 20° A.P.I. gravity oil. Drilling continued and finally the productive zone at the discovery well was reached. The section was cored and tested, but it was non-porous and yielded only a small gas flow and a trace of oil. It was decided to penetrate deeper into the Devonian for a more exhaustive test. At 5,375 feet, 288 feet stratigraphically below the top of the discovery zone in Leduc No. 1, extremely porous dolomite was encountered. A core showed excellent porosity and oil stain, and a drill-stem test brought oil to the surface in 7 minutes. Coring was continued to 5,423 feet and drilling completed on May 10, 1947. A second producing zone had been established in the Leduc field. After the formation water in the lower 10 feet was cemented off and after the production string was run, the well was brought in at the flush rate of more than 2,000 barrels a day.

On May 21, 1947, the same day that the Imperial's Leduc No. 2 was brought in, the Imperial's Leduc No. 3 began producing. This well, in Lsd. 10, Sec. 26, T. 50, R. 26, W. 4th Meridian, 2¾ miles northeast of the discovery well, produced from the lower zone and gave evidence of a productive strip 3¾ miles long and of unknown width, with indications that a major oil pool had been discovered.

Stratigraphy

PLEISTOCENE

The surface formation in the vicinity of the Leduc field is a variable thickness of glacial drift, with the exception of exposures of bedrock along the North Saskatchewan River and, rarely, along tributary creeks. The glacial drift is composed largely of clay, igneous boulders, gravel, and some sands, ranging in the Leduc field from 20 to 75 feet in thickness.

UPPER CRETACEOUS

Edmonton-Belly River Group

Bedrock outcroppings in the vicinity of the Leduc field are confined to ex-

posures of lenticular coal-bearing continental beds in the central part of the field along the North Saskatchewan River and in two small tributary creeks, one east and the other west of the field. These beds belong to the Upper Cretaceous Edmonton formation.

East and south of Leduc these non-marine beds are underlain by a series of marine shales and sandstones also Upper Cretaceous in age, termed the Bearpaw

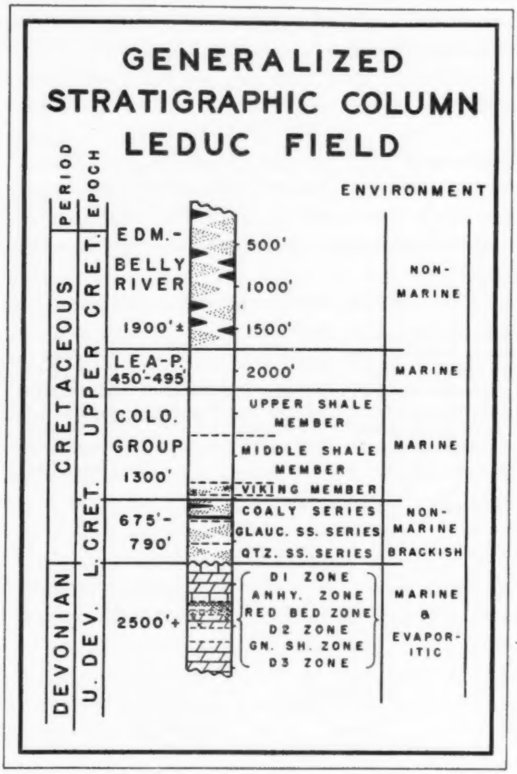


FIG. 3

formation, which overlies a section of non-marine, brackish, and continental beds termed the Belly River beds. In the Leduc field, however, no corresponding marine section has been recognized; as a result, the section of brackish and continental beds, which averages 1,900 feet in thickness (Fig. 3), is designated the Edmonton-Belly River group.

Lea Park Formation

Underlying these continental and brackish beds is a section of 450–495 feet of marine shales of Montana age, correlated with the Lea Park formation of

east-central Alberta (Fig. 3). The formation consists of dull gray, generally silty shale with some minor fine-grained, sandy phases. Glauconitic material occurs in the shales and silts, and thin ironstone concretionary beds are locally developed in the upper 250 feet. Bentonitic material is dispersed throughout the formation, but no well developed beds of pure bentonite have been reported.

The top of the formation is generally determined from electric logs and is placed at the base of the lowermost sand above the predominantly shale section. The base of the formation is placed at the top of the first dark gray shale containing minute cream- or buff-colored, calcareous specks, called the "First White Speckled Shale" and recognized as marking the Montana-Colorado boundary.

PALEONTOLOGY

No macrofossils have been obtained from the Lea Park formation in the Leduc area; however, some data are available on the microfauna, and the following identifications have been made by J. H. Wall of the Imperial Oil Limited geological staff. Microfossils from cuttings of the Imperial's Leduc No. 1 are the basis for this report.

The following Foraminifera were recognized.

Bolivina elkensis Nauss	*Gaudryina*
Bulimina venusae Nauss	*Gyroidina*
Epistomina fax Nauss	*Haplophragmoides*
Haplophragmoides glabra Cushman and Waters	*Lamarckina*
Neobulimina canadensis Cushman and Wickenden	*Robulus*
Trochammina ribstonensis Wickenden	*Saracenaria*
Verneuilina bearpawensis Wickenden	*Trochammina*
Anomalina	*Verneuilina*

The ostracod genus *Cytheridea* was also observed.

COLORADO GROUP

The Colorado group (Fig. 3) of marine beds has an average thickness of 1,300 feet and may be subdivided into the following four members in descending order.

Member	*Thickness (Feet)*
Upper shale	700
Middle shale	435
Viking	120
Lower shale	45

The Upper Shale member is a fairly homogeneous series of dark gray bentonitic shales, with minor beds of silty shales and ironstone concretions. This member underlies the Lea Park formation conformably, the top being placed at the top of the first dark gray shale with minute specks of cream- and buff-colored calcareous material. This zone, called the First White Speckled shale, is 50–100 feet thick and consists of an alternating series of speckled shale beds, dark gray, calcareous shale, and dark gray non-calcareous shale. The remainder of the Upper Shale member is made up almost entirely of dark gray shale and some ironstone concretionary beds. The base of the member is placed at the top of a second zone

of dark gray shale with cream- and buff-colored calcareous specks. This zone, called the Second White Speckled shale, differs from the First Speckled shale in being more indurated and having larger calcareous specks. In the Leduc field the top of this speckled shale zone is identified on electric logs.

The Middle Shale member averages 435 feet in thickness. The upper 200 feet is interbedded dark gray, calcareous shale, speckled shale, and dark gray bentonitic shale, with some very thin sand or silt lenses and bentonite beds. The lower part of this member is predominantly dark gray bentonitic shale. A bed of fine-grained, shaly, quartz sand 5–15 feet thick, containing abundant fish remains and plant spores, occurs approximately 300 feet below the top of the member. The base of this Middle Shale member is placed at the top of the black chert pebbles or cherty sand which mark the top of the Viking member.

The Viking member, which averages 120 feet in thickness in the Leduc field, is a series of dark gray shales, interbedded with fine- to medium-grained cherty and glauconitic sandstones. Conglomeratic phases of varicolored, well rounded chert pebbles, as much as $\frac{3}{4}$ inch in diameter, are present in some places. Locally the sands are fairly porous, and at the Viking-Kinsella gas field (75 miles east) they contain gas reserves estimated at a trillion cubic feet. In the Leduc field this sand zone has been tested in six wells, all of which showed gas and water, or gas alone. An analysis of the gas is included in the tables at the end of the paper. One well, the Imperial's Leduc No. 10, in Lsd. 11, Sec. 26, T. 50, R. 26, W. 4th Meridian, was completed as a gas well in this zone to supply fuel for drilling rigs. Where gas is present in this member in the Leduc field it appears to be confined to the upper sand lenses only, the lower sands being water-bearing in all wells on which information is reliable.

The base of the Viking member is placed at the base of a zone of silty shales and paper-thin lenticular fine-grained sandstones or silts, and in general is determined from electric-log curves.

The Lower Shale member, generally 45 feet thick, is a uniform zone of thin-bedded, dark gray, marine, bentonitic shales, commonly containing abundant pelecypod shell fragments 5–15 feet above its base, and some black and green chert pebbles at the base. The base of this member is placed at the top of the first non-marine beds.

There is some doubt about the Upper Cretaceous age of the Lower Shale member and the Viking member. Until definite paleontological evidence is available, the base of the Upper Cretaceous is arbitrarily placed at the contact of marine with non-marine beds.

PALEONTOLOGY

No recognizable macrofossils have been obtained from the Colorado group in the Leduc field, but the following preliminary data are available from microfaunal studies made by J. H. Wall of the Imperial Oil Limited geological staff, Calgary. Identifications were made of cuttings and cores from the Imperial's

Leduc well No. 1. Few cores were taken in the Upper Shale member. However, a considerable thickness is represented by core samples in the basal part of the Middle Shale member, and the entire Viking member and Lower Shale member were cored.

In the Upper Shale member the following Foraminifera of Turonian age and later were recognized.

Ammobaculites humei Nauss	*Ammobaculites*
Marssonella oxycona (Reuss)	*Anomalina*
Pullenia cretacea Cushman	*Bathysiphon*
Saccammina complanata (Franke)	*Clavulina*
Silicosigmoilina californica Cushman and Church	*Gaudryina*
Globigerina	*Spiroplectammina*
Haplophragmoides	*Textularia*
Marginulina	*Verneuilina*
Nonion	*Trochammina*
Robulus	

The following Foraminifera have been identified in the Middle Shale member. The same fauna occurs in the Viking member and possible Albian age is indicated.

Ammobaculites fragmentaria Cushman	*Verneuilina canadensis* Cushman
Ammobaculites tyrrelli Nauss	*Ammobaculites*
Miliammina manitobensis Wickenden	*Haplophragmoides*
Miliammina sproulei Nauss	*Verneuilina*

The age of the Lower Shale member is probably Albian as indicated by its foraminiferal content. For lithological reasons an Upper Cretaceous age has been assigned by most geologists to this basal 50 feet of the Colorado group. The Foraminifera identified in the Leduc field are listed.

Ammobaculites tyrrelli Nauss	*Ammodiscus*
Gaudryina hectori Nauss	*Haplophragmoides*
Haplophragmoides gigas Cushman	*Gaudryina*
Haplophragmoides linki Nauss	*Miliammina*
Ammobaculites	*Spiroplectammina*

LOWER CRETACEOUS

The Lower Cretaceous in the proved area is 675–850 feet thick. It is conformably overlain by the Lower Shale member of the Colorado group, and lies unconformably on an eroded Upper Devonian surface.

These beds consist of continental to brackish, interbedded sands, shales, silts, coal, and carbonaceous beds; some thin shale bands may be marine in origin. In spite of the lenticular character of most of the silts and sandstones, the assemblage may be subdivided into various members which are applicable not only in the Leduc field but may be extended over a wide region.

In the Leduc field it is customary to divide these beds into three parts. Undoubtedly these could be classified as members, although, at present, this does not appear advisable. These three divisions are of possible economic value in the field because of potential reservoir sands in each of them. They are listed here in descending order.

	Thickness (Feet)
Coaly series	230
Glauconitic sand series	255
Quartz sand series	175–350

The Coaly series, which has an almost constant thickness throughout the field, is overlain conformably by the Lower Shale member of the Colorado. Approximately the upper 100 feet are composed of a heterogeneous mixture of fine-grained, kaolinitic sandstones and drab gray siltstones, in part cross-bedded, and commonly containing carbonaceous material, either included, or as thin laminae along bedding planes. Shales are present, ranging from those containing a relatively small amount of carbonaceous material and plant fragments to coaly shales, associated with thin, lenticular, poor-grade coal seams. A relatively persistent coal and coaly shale bed, as much as 10 feet in thickness, occurs 100 feet below the top. Below this are approximately 120 feet of interbedded, dull gray, carbonaceous shales and silts, with a persistent bed of coal and coaly shale, ranging from 5 to 15 feet in thickness, at the base of the series.

Locally, a sandstone as much as 50 feet in thickness overlies the basal coal. In the field the sandstone is saturated with heavy black oil, but in the wells permeability and porosity are extremely low.

The Glauconitic Sand series, 255 feet thick, may be divided into two parts, the upper 150 feet being largely salt-and-pepper sandstones in part with calcareous cement, and dull gray, soft, bentonitic and carbonaceous shales, very similar in appearance to the beds above the persistent coal seam. Underlying these beds is a zone of interbedded, gray shales and very fine- to medium-grained quartz sandstone, the latter containing varying amounts of glauconite. Generally the sands and shales are very thinly interbedded, but well sorted lenses of sand occur locally, and show slight oil stain. No tests of the sand have been made, but electro-log data indicate that it may yield appreciable quantities of gas throughout the field. The base of this glauconitic sand series is placed at the top of the first dark gray shale, in part calcareous, containing abundant ostracods and pelecypods, and some gastropods.

Underlying the Glauconitic Sand series is a section of interbedded, dark gray shales and fine-grained quartz sandstones called the Quartz Sand series. It varies in thickness from 175 to 350 feet, and rests unconformably on the eroded Devonian surface. The top is marked by a bed of dark gray shale approximately 20 feet thick, in places interbedded with fine-grained quartz sands, and containing an abundant ostracod and pelecypod fauna. This is an excellent marker bed.

Underlying the ostracod zone, shales of similar type, but non-calcareous, are interbedded with lenticular quartz sandstones. Individual sandstone beds range from a fraction of an inch to 30 feet in thickness, and range from hard, calcareous cemented sandstones to soft, friable, porous sands. The sands are fine- to very fine-grained, and are composed almost entirely of clear quartz grains which are angular to subangular, to crystalline, with very minor amounts of chert. On the

basis of drill-stem tests and a preliminary study of electric logs and sample cuttings it seems probable that, in local areas, appreciable quantities of gas and possibly oil are present. Analyses of the oil, water, and gas in these beds are included in the accompanying tables.

PALEONTOLOGY

No Foraminifera have been reported in the Lower Cretaceous beds in the Leduc field, though some are probably present and will be found by more detailed work. The only fossiliferous zone in the Lower Cretaceous beds of this area is the Ostracod zone marking the top of the Quartz Sand series. Pelecypods and gastropods are present, but the specimens are insufficiently preserved for identification. A good assemblage of ostracods is present. Faunas recovered from cores taken at the Imperial's Leduc No. 1 have been identified as follows by Miss Diane Loranger of the Imperial Oil Limited geological staff, Calgary, Alberta.

Metacypris angularis Peck
Metacypris persulcata Peck
Bairdia sp.
Candona stirlingensis
Cypridea anomala Peck

Due to the paucity of fossil information about the Lower Cretaceous in the Leduc field, correlation of these beds must depend to a large extent on subsurface regional studies. They are probably Aptian in age.

DEVONIAN

Underlying the Lower Cretaceous beds unconformably in the Leduc area is a section of Devonian dolomites, limestones, marine shales, and some evaporites. The greatest thickness of these sediments penetrated to date in the Leduc area is 2,700 feet drilled in the B. A. Pyrcz No. 1, at the east edge of the field in Lsd. 12, Sec. 25, T. 50, R. 26, W. 4th Meridian. The only other well in the immediate area which has penetrated below the stratigraphic position of the lower producing zone is the Okalta's Leduc No. 1, in Lsd. 13, Sec. 7, T. 50, R. 25, W. 4th Meridian. This well was drilled off structure and penetrated 1,725 feet of Devonian beds before being abandoned. In the productive area the producing zones lie at depths between 600 and 1,000 feet below the Devonian contact. In consequence the information on the Devonian section at this early stage of development is largely confined to the upper 1,000 feet.

When oil was discovered in Devonian beds at Leduc, it was realized that no known formational or member names could be used until an intensive study had been made of the section. Paleontological evidence was, and still is, extremely scarce, and an understanding of the facies changes and their relationship to stratigraphic horizons is far from complete. For these reasons, a temporary terminology was used. This obviated the necessity of adding to an already over-burdened nomenclature and, at the same time, subdivided the Leduc Devonian section into lithological units, making possible intelligent discussion of the various members (Fig. 4). These members or zones, as they have been termed, are here listed in

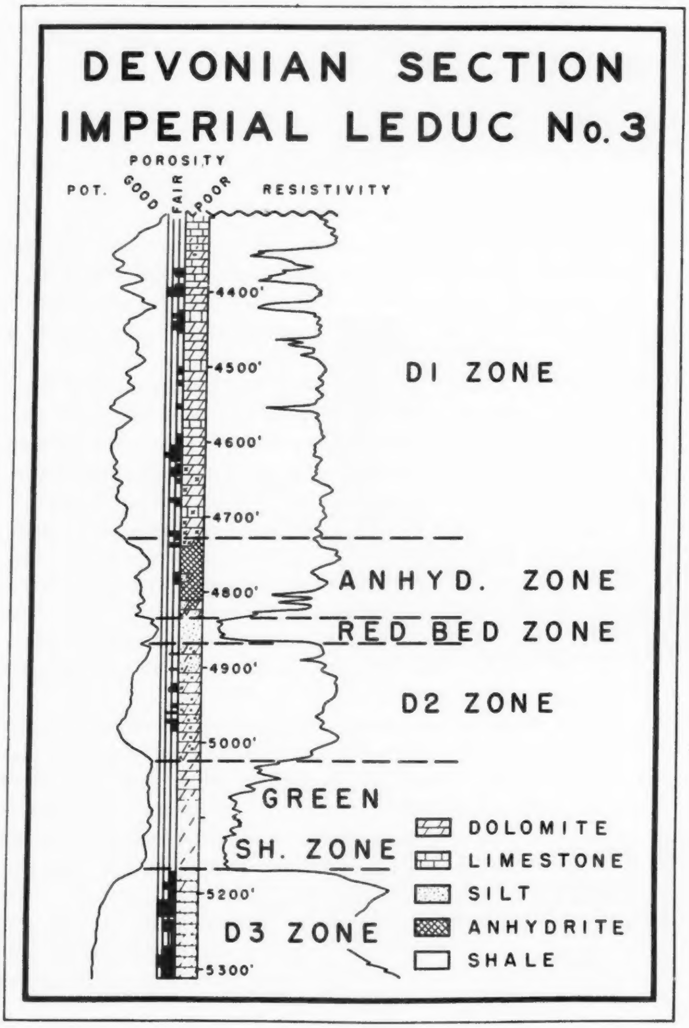

DEVONIAN SECTION
IMPERIAL LEDUC No. 3
POROSITY
POT.
GOOD
FAIR
POOR
RESISTIVITY
4400'
4500'
4600'
4700'
4800'
4900'
5000'
5200'
5300'
DI ZONE
ANHYD. ZONE
RED BED ZONE
D2 ZONE
GREEN
SH. ZONE
D3 ZONE
DOLOMITE
LIMESTONE
SILT
ANHYDRITE
SHALE

FIG. 4

descending order, with their range of thickness in the proved area. All are believed to be Upper Devonian in age.

Zone	*Thickness (Feet)*
D-1	220–460
Anhydrite	80–190
Red Bed	30– 40
D-2 (Discovery zone at well No. 1)	145–165
Green shale	125–225
D-3 (Discovery zone at well No. 2)	165

D-1 Zone

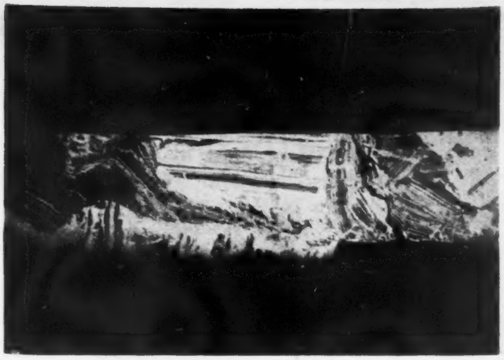
This zone underlies the Lower Cretaceous beds unconformably, and ranges in thickness from 220 to 460 feet. It is composed largely of dolomites, limestones, and dolomitic limestones, with traces of secondary anhydrite and chert. The top of this zone is placed at the top of the first marine limestone or dolomite, and the base at the top of the first occurrence of bedded anhydrite.

The zone is characterized by fine intermixing and interbedding of dolomitized limestones, dense dolomites, limestones, and gradations of dolomitic limestones. Sample cuttings are difficult to evaluate because of this close intermixture. Fortunately, electric logs have provided valuable additional data for correlation in this part of the section. The upper part of the D-1 zone, where present, is composed of a section, as much as 75 feet in thickness, of dense, buff to gray-buff limestones, dense buff dolomites, and buff to brown dolomitic limestones. Fractures are common, and practically all of them are sealed with secondary calcite, dolomite, and, in some places, anhydrite or clastic material. Thin, greenish gray, irregularly bedded shale bands are present, as are traces of gray and gray-blue nodular chert. Very little evidence of oil stain is present, although some traces of dark brown oil occur along a few fractures.

Underlying this predominantly dense series are beds of variable thickness, in part composed apparently of solution breccia. Brecciation does not appear to have occurred on a massive scale, but rather by minor displacement of thin-bedded dolomites and dolomitic limestones (Pl. 1). Some fragments are oil-stained, others are flushed, and, in most, the brecciation fractures are sealed by recrystallization. It is believed that this brecciation is a result of solution of thin anhydrite beds during pre-Cretaceous erosion. Later fracturing of this rock apparently occurred after recrystallization along the brecciation fractures, probably during the period of compaction in Cretaceous and post-Cretaceous time. Most of these secondary fractures are re-sealed, but some are still sufficiently open to show well developed oil stain along their edges.

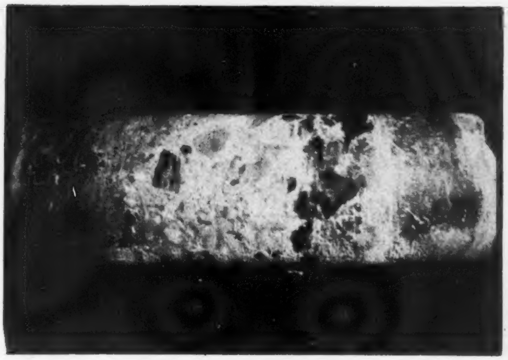
This brecciated material is interbedded with, and grades into, a series of oölitic dolomites and limestones and dolomitic limestones. Most of these dolomites hold evidence of dolomitized fossil fragments, mostly algal or oölitic material. Although this part of the D-1 zone has not been cored completely, sample studies point to the presence of interbedded, dense dolomites, and crystalline, in

Diamond core from
D1 ZONE LEDUC FIELD
showing highly brecciated material occurring in upper part of zone. Dark bands are caused by concentration of heavy gravity oil along more porous bands.



Scale in inches
0 1 2 3 4 5 6

Diamond core from
D1 ZONE LEDUC FIELD
showing brecciated fragmentory material occurring in upper part of zone. Dark fragments are saturated with heavy gravity oil.



Scale in inches
0 1 2 3 4 5

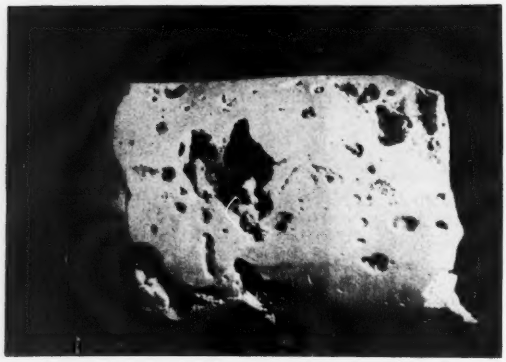
Diamond core from
D1 ZONE LEDUC FIELD
showing minor brecciation typical of upper part of zone believed to be largely a result of leaching out of thin anhydrite beds. Dark bands are due to heavy oil staining.

Scale in inches
0 1 2 3 4

Diamond core from
D_2 ZONE LEDUC FIELD
showing vug porosity developed in leached out coralline material. Fine septa like markings noticeable in some pores is secondary $CaSO_4$.

Scale in inches
0 1 2 3 4

Diamond core from
D_3 ZONE LEDUC FIELD
showing large vugs and complete lack of bedding, typical of this reservoir.



Scale in inches
0 1 2 3 4

Diamond core from
D_3 ZONE LEDUC FIELD
showing typical vuggy character of reservoir. Oblique alignment of vugs in core is thought to be due to depositional slope on steep east face of reef.

Scale in inches
0 1 2 3 4 5 6

PLATE 2

part porous, secondary dolomites. Porosity is both intergranular and intermediate, some of which has been destroyed by the deposition of secondary anhydrite.

On the basis of the drill-stem testing on the first three wells drilled by the Imperial Oil Limited, it appears that the upper 200 feet of the D-1 zone are composed of a series of lenticular, porous zones. Analyses of gas, oil, and water from this zone are included in Tables I, II, and III. No structural or stratigraphic relationship has been determined for these small, lenticular zones and at present the amount of oil or gas is too minor to warrant detailed testing. In some places in the field this part of the Devonian section may be proved economically important, especially as production declines from the main producing zones. The lower 200–250 feet of the D-1 zone contain beds of well developed porosity, but they are apparently water-bearing in the south half of the field. North of the North Saskatchewan River, at the Imperial Woodbend No. 1, a drill-stem test in this lower part of the zone gave a 450-foot rise of 38.5° A.P.I. gravity crude accompanied by salt water. It is possible, therefore, that some oil may be produced in the north part of the field.

Correlation of the D-1 zone between wells in the productive area indicates no evidence of appreciable thickening or thinning, the changes in thickness being due to variations in the depth of erosion at the old Paleozoic erosional surface. The greatest depths of erosion recorded at present are at the west side of the field at the Globe-Leduc's West No. 1, in Lsd. 6, Sec. 19, T. 50, R. 26, W. 4th Meridian, where only 290 feet of the D-1 zone remain, and at the Imperial's Woodbend No. 1, where the D-1 zone is only 222 feet thick.

Anhydrite Zone

Underlying the D-1 zone is a variable thickness of white, gray, and buff, bedded anhydrites, with some dolomite and silt in the lower part. The top of this zone may be determined easily both from sample examination and from its characteristic effect on electric-log curves. The bottom of the zone is placed at the top of the first red and green, mottled siltstone, a bed easily recognizable both from lithological and electric-log data (Fig. 4). The anhydrite zone thins northeastward across the field; it is 190 feet thick at the East Leduc-South Brazeau No. 1 in Lsd. 8, Sec. 9, T. 50, R. 20, W. 4th Meridian, and 180 feet thick at the Globe-Leduc West No. 1 in Lsd. 6, Sec. 19, T. 50, R. 26, W. 4th Meridian, thinning to only 85 feet at the Imperial's Leduc No. 14 on the east side of the field in Lsd. 9, Sec. 26, T. 50, R. 26, W. 4th Meridian.

The anhydrite zone may be divided into two parts: an upper part composed almost entirely of bedded anhydrite, increasing in thickness from 10 to 126 feet southwestward, and a lower part ranging from 65 to 85 feet in thickness, composed of finely crystalline to dense, buff, silty dolomites interbedded with slightly silty anhydrites. This silty phase in the lower part of the anhydrite zone is the upper part of the Darling silt, discussed later. The dolomites in this part of the anhydrite zone are in general very finely crystalline, and, although in part stained

TABLE I

OIL ANALYSES (DISTILLATION OF WATER-FREE CRUDE)

Zone	Gravity (°A.P.I.)	Color (Saybolt)	Init. B.P. (° F.)	Percentage Off at Temperature in Degrees Fahrenheit																Final B.P. (° F.)
				158	212	221	257	284	302	356	374	392	400	437	460	500	560	600	650	
Lower Cretaceous	27.1	Dark brown	140	1.0	5.0	6.5	12.0	16.5	19.0	25.0	27.5	30.0	31.0	33.5	37.0	41.5	48.0	55.5		610
D-1 Zone	21.0	Black	130	1.0	2.5	3.0	4.0	6.0		11.5	13.0		15.0		21.0	25.0	31.0	36.0	45	668
D-2 Zone	38.2	Dark brown	120	2.0	7.0	9.0	15.0	19.0		30.0			35.0		42.0	47.0	53.0	60.0	65	700
D-3 Zone	38.8	Dark brown	120	2.0	7.0	9.0	15.0	19.0		30.0	32.0		37.0		44.0	48.0	57.0	61.0	68	700

TABLE II

GAS ANALYSES (PODBRIELNIAK)

Zone	Composition in Volume Percentage								Remarks
	Methane	Ethane	Propane	Iso-butane	N-butane	Iso-pentane	N-pentane	Di-iso-propyl plus	
Viking sand	91.21	4.26	2.62	0.45	0.81	0.16	0.25	0.24	Sample from separator at 170 psig.
Lower Cretaceous quartz sand	82.11	7.80	2.86	0.32	0.85	0.23	0.28	0.35	Taken from flow line in D.S.T.
D-1 Zone	83.91	7.49	2.84	0.27	0.76	0.18	0.21	0.34	Taken from flow line in D.S.T.
D-3 Zone	75.86	15.88	6.06	0.51	1.15	0.18	0.17	0.19	Sample from separator at 200 psig.

with light oil, they have not shown favorable results in tests. The percentage of dolomite in the anhydrite zone increases markedly east and north. In a short distance beyond the Leduc field, only dolomites are present, and it becomes impossible to differentiate this zone from the overlying D-1 zone.

RED BED ZONE

Underlying the anhydrite zone is an excellent marker bed 30–40 feet thick. This zone is a red and green mottled siltstone composed of 75–90 per cent quartz grains. The average grain size is 0.04–0.08 millimeter. The grains are imbedded in red and green argillaceous material. The zone is easily recognizable in drilling because of its coloration of the mud. It is relatively simple to determine from well cuttings, and it gives an extremely characteristic "kick" on the self-potential and resistivity curves of the electric logs (Fig. 4). The base of this zone is sharply defined by an abrupt change from green and red siltstone to buff, silty dolomite with anhydrite-filled vugs. In some places a few inches of well cemented, rubbly breccia occur at the base. The zone is recognizable in an exceptionally wide area beyond the productive area of the field, although its red coloration is generally absent.

TABLE III

WATER ANALYSES

Zone	*Composition in Parts per Million*							*Total Solids by Analysis*	H_2S	*S.C. 60°/60° F.*
	Sodium	*Calcium*	*Magnesium*	*Chloride*	*Sulphate*	*Bicarbonate*	*Carbonate*			
Lower Cretaceous quartz sandstone	32,010	5,430	1,080	61,600	294	555	—	100,969	Nil	1,073
D-1 Zone	31,410	6,590	1,400	63,470	471	652	—	103,993	—	1,075
D-2 Zone	48,090	13,150	3,350	106,800	465	111	—	171,966	Trace	1,123
D-3 Zone	41,140	26,810	3,780	121,300	590	320	—	193,940	Nil	1,136

D-2 ZONE

The D-2 zone, underlying the Red Bed zone, is the original oil-producing zone of the Leduc field. Throughout the field it ranges in thickness from 135 to 170 feet. The top is placed at the top of the first buff, crystalline, silty dolomite, generally containing anhydrite-filled vugs. The base is placed at the top of the first appreciable thickness of greenish gray shale. However, for practical purposes in the field, the base is generally determined from electric-log curves (Fig. 4).

The D-2 zone is divisible into three units varying somewhat in thickness and character, but recognizable throughout the field. The upper 35–50 feet is silty, buff-colored, finely crystalline dolomite containing some vugs, most of which are filled with white anhydrite. A persistent, 3-foot bed of greenish, argillaceous silt occurs 20–25 feet below the top throughout the field, and appears to delineate the upper boundary of the producing zone.

The middle unit of the D-2 zone, which is the oil reservoir, is a fossiliferous, buff, crystalline to dense dolomitized limestone, with variable amounts of secondary anhydrite (Pl. 2). Porosity is of intercrystalline and vug type, the latter being due to organic remains. Secondary anhydrite is present throughout the field as intercrystalline and vug filling; and in the non-productive areas along the steep east flanks of the D-3 producing zone the lack of porosity and permeability is apparently a direct result of excessive deposition of secondary anhydrite. The average thickness of the producing zone is 35 feet. This unit grades into a series of dense to finely crystalline, brownish to buff dolomites, which become argillaceous with depth. Anhydrite inclusions, commonly pink to reddish in color, are abundant. Some of the argillaceous dolomites are stained red with iron oxide, and some poorly preserved microscopic hematite crystals are scattered along bedding planes and fractures.

Green Shale Zone

The Green Shale zone, which underlies the D-2 zone, increases in thickness from 125 feet at the south end of the proved area to 225 feet on the eastern productive limits, with a further pronounced thickening beyond the east edge of the structure. The upper part of the Green Shale zone is generally interbedded, argillaceous dolomite, gray, greenish gray, and buff, with some reddish stain, and grayish dolomitic shale, transitional from the base of the D-2 zone. This section of interbedded material grades downward into greenish gray dolomitic shales overlying the dolomites of the D-3 zone. Some brachiopod, coral, and bryozoan fragments occur near the base, but to date, none has been found sufficiently preserved for identification.

D-3 Zone

The D-3 zone, which is the lowest producing zone, has been penetrated to a depth of only 165 feet in the productive area. Its contact with the overlying green shale is extremely sharp and is commonly marked by concentrations of pyrite throughout a thickness of as much as 2 or 3 inches. The part of the D-3 zone penetrated in the proved area is buff, crystalline dolomite with many vugs and intercrystalline porosity, numerous open fractures and no evidence of bedding (Pl. 2). A few casts of brachiopods are present, and coralline and bryozoan material is abundant. There seems little doubt that the D-3 zone is a reef limestone which has been completely dolomitized. Pyrobitumen completely or partly fills the vugs and fractures in the gas zone, but is relatively rare in the oil zone. Oil stain is evident throughout the section, but in cores is noticeable only in areas where permeability is relatively low.

Although none of the wells in the productive area has drilled a complete section of the D-3 zone, some information is available from the B. A. Pyrcz No. 1. This test, in Lsd. 12, Sec. 25, T. 50, R. 26, W. 4th Meridian, is $\frac{1}{4}$ mile due east of the Imperial's Leduc No. 14, and $\frac{3}{8}$ mile south of the Pyrcz No. 2, both of which produce from the D-3 zone. This test encountered the D-3 zone at the subsea

elevation of 3,017 feet, which is approximately the elevation of the oil-water interface in the Leduc field. Drilling was continued at this well for an additional 1,683 feet and, excepting the Okalta Leduc No. 1, it affords the only near-by source of information on the strata below the upper part of the D-3 zone. A very abbreviated log of the Devonian section penetrated at the B. A. Pyrcz No. 1 follows.

Depth (Feet)	*Description*
4,310	Top of D-1 zone
4,770	Top of Anhydrite zone
4,865	Top of Red Bed zone
4,900	Top of D-2 zone
5,065	Top of Green Shale zone
5,327	Top of D-3 zone
5,327–5,635	Dolomite, cream to buff, crystalline and dense, intercrystalline and vuggy porosity well developed
5,635–5,915	Dolomite, dark brown, crystalline and dense, intercrystalline and vuggy porosity present; becomes less crystalline near base
5,915–6,890	Limestone, gray and dark brown, dense to finely crystalline limestone, in part argillaceous, with some gray calcareous shale
6,890–7,010	Shale and dolomite, red, green, and brown shales with brown, argillaceous limestone, and traces of finely granular dolomitic limestone at base

As the Green Shale zone at this test was approximately 90 feet thicker than at the Imperial's Leduc No. 14, $\frac{1}{4}$ mile west, it therefore seems probable that porous dolomites in the B. A. Pyrcz No. 1 are 100–150 feet thinner than the maximum in the producing area. No base has been drawn for the D-3 zone on the information from this deep test, but, although the dolomite from 5,327 to 5,915 feet lacks any well developed lithological breaks, probably a division could be drawn on the basis of the color change at 5,635 feet.

There is some doubt that this test was still in Upper Devonian beds when it was abandoned, but as no paleontological evidence is available a definite statement can not be made.

The only other well drilled below the stratigraphic equivalents of the upper part of the D-3 zone is the Okalta-Leduc No. 1 in Lsd. 13, Sec. 7, T. 50, R. 25, W. 4th Meridian. This location is $2\frac{1}{2}$ miles south, and 1 mile east of the B. A. Pyrcz No. 1, and 3 miles due east of the nearest producer, the Imperial's Leduc No. 7. The Okalta-Leduc No. 1 was drilled through a normal section to the base of the D-2 zone at 5,150 feet, but found no recognizable D-3 zone. Below 470 feet of greenish gray shales, black and brown, petroliferous, conodont-bearing shales, interbedded with dark brown, dense limestones, were encountered at 5,620 feet. From 5,810 feet, dark brown crystalline dolomites, in part porous, continued to 6,010 feet. The remainder of the section to the total depth of 6,110 feet was dark gray limestone.

Darling Silt

The silt in the Leduc field was studied in detail by G. B. Darling of the Imperial Oil Limited geological staff, Calgary, Alberta, and the following comments are based on his work.

The silt ranges from 130 to 175 feet in thickness; the first trace occurs 65–85 feet above the base of the Anhydrite zone, and the last evidence is 35–50 feet below the top of the D-2 zone. In the Anhydrite zone the silt forms 2–65 per cent by volume of the rock; in the Red Bed zone it forms 75–90 per cent; and in the upper part of the D-2 zone it ranges from 1 to 15 per cent of the total volume. The silt is composed of quartz grains; no accessory minerals have been identified. The quartz grains vary from smooth to angular, and some crystal faces are still preserved. The grain size ranges from 0.02 mm. to 1.2 mm., and averages 0.04–0.08 mm. The coarser material appears to be more prevalent in the upper part and, although for correct usage part of the clastic material should be termed fine sand, the term silt is used for the whole interval.

Sedimentology of D-2 and D-3 Zones

In the initial exploration stages of an oil field producing from dolomite reservoirs the problems relating to an understanding of the reservoirs are probably more complex than those encountered in any other type of reservoir. In full realization of this fact, the Imperial Oil Limited, the major operator in the field, began a program of intensive coring of the D-2 and D-3 zones. At first, cores were taken by means of wire-line and conventional methods, but coring with a diamond core bit was begun late in 1947. Company petroleum engineers and geologists thus have plentiful data, detailed studies of which are now being made.

Some interpretations of the sedimentation and later modifications of the D-2 and D-3 zones are discussed in subsequent paragraphs. Based on preliminary examination of thin sections, polished sections, and microscopic examination of cores, as well as regional studies of the Devonian in the Western Canada Basin area, it must be realized that the conclusions are still highly tentative.

It is apparent from a very cursory examination of the lithologic character of the D-2 and D-3 zones that there are certain similarities and dissimilarities. Both are predominantly dolomite, and neither contains beds of limestone. Completely dolomitized coral and bryozoan material is abundant in both zones. Open fractures are also present in both zones. Both intercrystalline and vug porosity are present, although the latter is better developed in the D-3 zone.

Secondary anhydrite partly or completely fills all vugs in the D-2 zone, but is absent in the D-3 zone. The D-2 zone has an almost uniform thickness, not only throughout the field but in an area of 6,500 square miles surrounding the Leduc field. The D-3 zone, or at least that part of it penetrated to date in the productive area of the Leduc field, is uniform, massive, highly porous dolomite with a complete lack of bedding. If all the porous dolomite encountered in the B. A. Pyrcz No. 1 is considered one unit, the thickness is 600 feet; whereas at the Okalta Leduc No. 1, 2½ miles south, it is only 200 feet. No porous dolomites equivalent to the D-3 zone are present 30 miles southwest at the Imperial's Battle Lake well, although 35 miles north a section of 1,100 feet of largely porous dolomites is present in the wildcat wells drilled by the Imperial at Morinville and Legal, Alberta.

A satisfactory picture of the origin and development of the Leduc reservoir zones is far from complete, but it may be of some value to offer a working hypothesis.

It is believed that shallow-water conditions caused by regional uplifts resulted in the deposition of shallow-water limestones which stimulated rapid organic growth, and that D-3 limestone reefs began to develop in local areas along positive trends. Reef growth continued for a variable length of time, depending on its position relative to the deepening parts of the basin, but was not directly related to shoreline conditions. Rapid deposition of marine muds apparently stopped the reef growth. Gradually the sea bottom over a broad area shallowed, and conditions again became suitable for the existence of reef-building organisms (D-2 zone). However, there apparently was a continuation of the slow rising of the major part of the Western Canada Basin area relative to the shelf areas associated with the geosynclinal belt, and conditions did not long remain suitable for reef development, even in the Leduc area. Southward, highly saline waters apparently killed off the reef-building organisms at various periods during the deposition of the D-2 zone, while on the north and west the water was not suitable for active growth. In the Leduc area the environment was comparable with the favorable conditions prevalent during the growth of the D-3 reef for only very short intervals. The organisms were then smothered under the sudden deposition of fine silt which almost completely stopped all reef building. This was followed by a further shallowing and draining-off of the sea waters, probably accompanied by a deepening of the geosynclinal belt and shelf area. Widespread anhydrite deposition resulted and continued for a short time in the Leduc area. It is probable that solution of the D-2 zone occurred during and after this period, and that the deposition of secondary anhydrite in vugs and intercrystalline pores began. South and southeast, however, evaporite conditions prevailed almost continuously until the end of Devonian time.

PALEONTOLOGY

The Devonian in the Leduc field has not as yet yielded macrofossils in a state of preservation suitable for identification. Crinoid columns and fragments of brachiopod shells are present in the upper 75 feet of the D-1 zone. Stromatoporoid fragments and unidentifiable dolomitized, structureless corals are abundant throughout the zone. Some bryozoans are reported from the D-2 and D-3 zones, along with dolomitized casts of brachiopod shells and abundant coral material.

A Devonian fauna from various wildcat wells in central Alberta has been examined and reported by P. S. Warren[4] of the University of Alberta.

Preliminary studies on the microfauna of the Leduc Devonian have been begun. However, the necessity of preparing acid residues for these studies has resulted in slow progress. As a result, most of the determinations have been based

[4] Read before the Alberta Society of Petroleum Geologists, 1947. This *Bulletin*, pp. 564-71.

on examination of thin sections and sample disintegrates. The faunas discussed below have been identified by Miss Diane Loranger of the Imperial Oil Limited geological staff.

In thin sections made from cores taken in the D-1 zone, scaphopods, echinoids, and some plant fragments thought to be "oogonia" were found, as well as some unidentifiable ostracods and colonial corals.

No microfaunas have been reported from the Anhydrite, Red Bed, or D-2 zones. Two fairly common scolecodonts (*Arabellites magnificus*, *Oenonites orthodontus*) were reported at the top of the D-3 zone in one well, and echinoids, coral fragments, and "oogonia" occur throughout.

Microfossils are somewhat more abundant in the Green Shale zone underlying the D-2 zone. In the Okalta Leduc No. 1 the following forms, occurring 300 feet below the top of the D-2 zone, were recognized: *Tentaculites* sp., *Lingula* sp., *Bairdia* sp., and some long-ranging conodonts largely of the genus *Hindeodella*. Approximately 400 feet lower, in black shales and limestones, an excellent assemblage was found, which consisted of scolecodonts, ostracods, and diagnostic conodonts, associated with fish remains, bryozoans, and echinoids. *Nereidavus planus*, *Polygnathus* sp., *Diplodella* sp., and *Icriodus symmetricus* place the age as Upper Devonian. *Lignoidina* cf. *franklinensis*, *Hindeodella* sp., *H.* cf. *aculeata*, *Ponderodictya* sp., *Paraparchites* sp., and *Cytherella incognita* were also present.

A complete conodont assemblage was found in cores from the Millet Leduc well, and although this well is not in the Leduc field, it is believed that the fauna is sufficiently important to warrant being reported in this paper. The Millet Leduc test was located 15 miles south of the Leduc field and was abandoned at the depth of 6,255 feet. The fauna here listed was found in a cored section of interbedded black, petroliferous shales and dense, brown limestones, 875 feet below the top of the D-2 zone.

> *Palmatolepis* sp., *Hindeodella* sp., *Lonchodus* sp., *Polylophodonts* sp., *Ctenognathus* sp., *Polygnathus* sp., *Apatognathus* sp., *Ligonodina* sp., *Euprioniodina* sp., *Bryantodus* sp., *Ancyrodella* sp., *Prioniodus* sp.

On the basis of regional studies, a tentative correlation of the Devonian section at Leduc has been made with various sections published by Sloss and Laird.[5] The Devonian rocks at Leduc are considered to be Chautauquan in age down to the base of the D-2 zone. This age correlation depends for its validity largely on the range of *Cyrtospirifer whitneyi* as recognized by Sloss and Laird.

Structural Geology

The Leduc oil field is on the Alberta homoclinal belt, as shown in Figure 2. Regional dips are 43 feet per mile southwest in the Devonian, and average 26 feet per mile southwest in the Cretaceous; the discrepancy in these dips indicates the degree of angularity at the Devonian-Cretaceous nonconformity.

[5] L. L. Sloss and W. M. Laird, "Devonian System in Central and Northwestern Montana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 8 (August, 1947), pp. 1404–30.

The structure of the oil field, insofar as present data permit interpretation, is illustrated by a cross section (Fig. 5), and by contour maps on the D-3 (Fig. 6) and D-2 (Fig. 7) reservoir beds and on the electric-log marker, E26 (Fig. 8) approximately 90 feet below the top of the Colorado group.

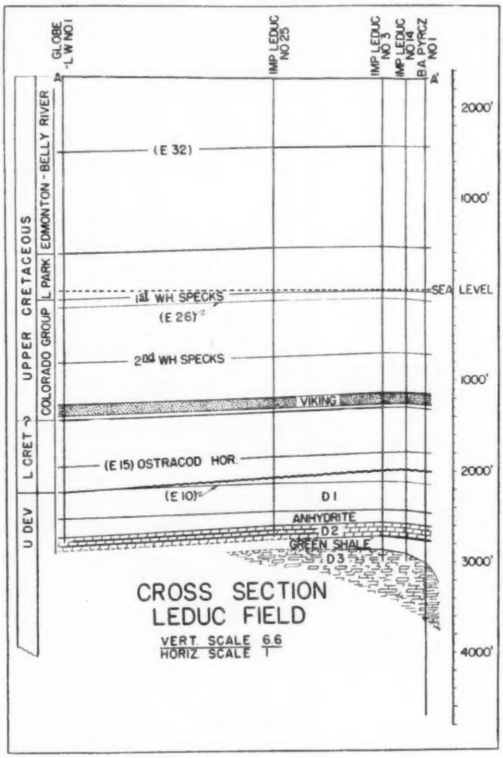


FIG. 5

These structural maps and sections reveal an appreciable arching of all recognizable marker beds across the field. The degree of arching on various marker beds is as follows. 1. Arching on the top of the Devonian D-3 zone is the most accentuated. This arching is considered to be depositional in origin (Fig. 6). 2. Arching on the top of the Devonian D-2 zone is the next most accentuated, but is much less than on the D-3 zone (Fig. 7). 3. The Devonian-Cretaceous nonconformity is arched across the field. 4. Arching of Cretaceous marker beds up to the top of the Lea Park formation is in excellent parallelism, but is less accentuated than that of any of the Devonian marker beds (Fig. 8).

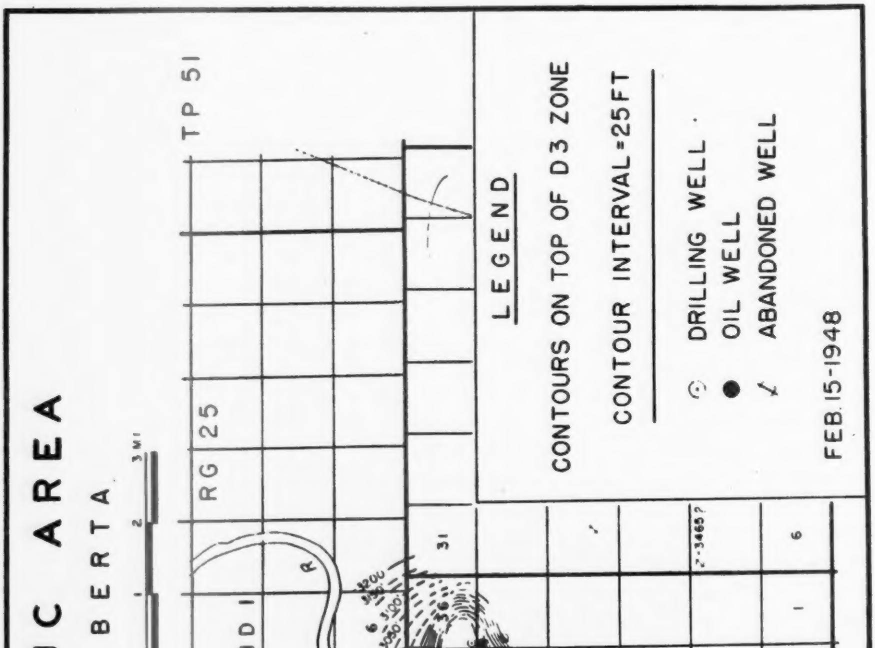

LEDUC AREA
ALBERTA
LEGEND
CONTOURS ON TOP OF D3 ZONE
CONTOUR INTERVAL = 25 FT
DRILLING WELL
OIL WELL
ABANDONED WELL
FEB. 15-1948
TP 51
TP 50
TP 51
RG 26
RG 25
WOODBEND I
IMP.
DEVON
S A S K. R
DISCOVERY WELL
3000
3100
3200
2900
2850
6
31
36
1
6

FIG. 6

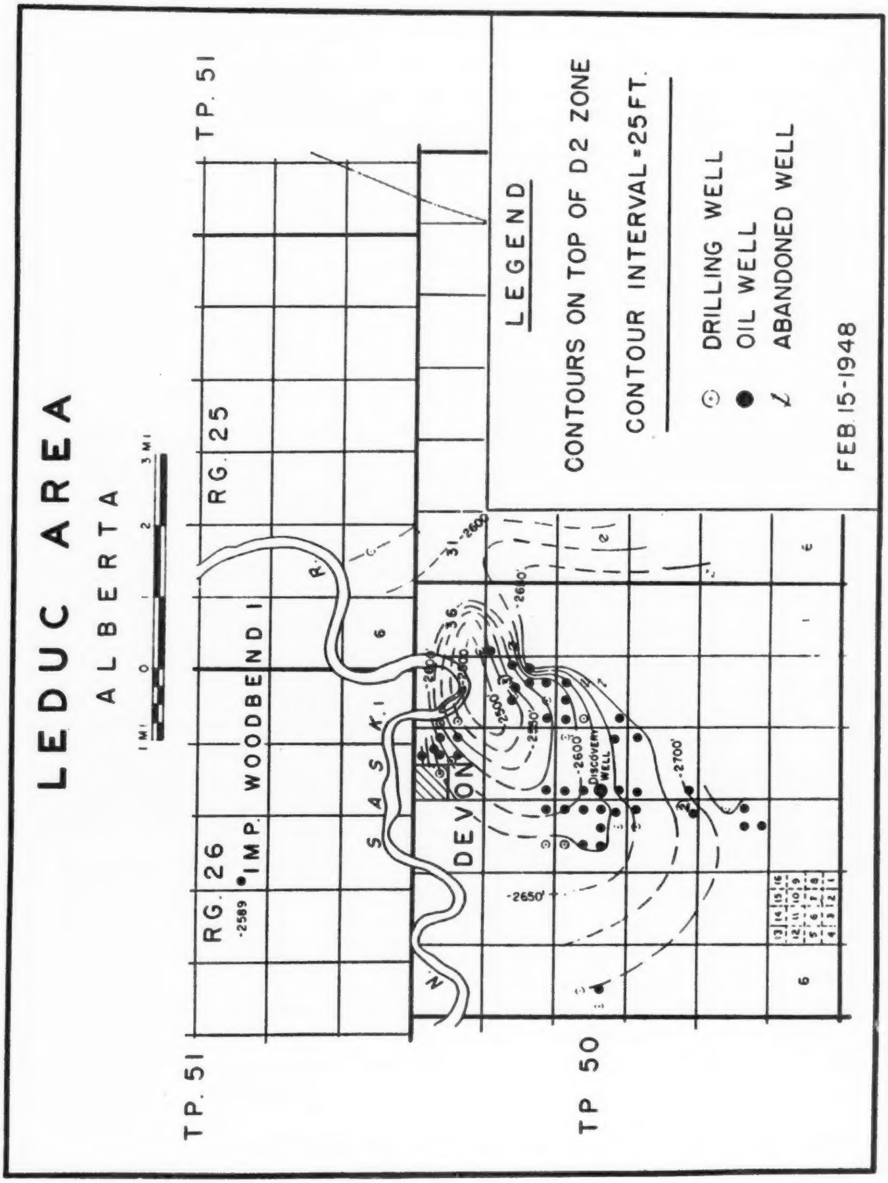

LEDUC AREA
ALBERTA
1 MI 0 1 2 3 MI
TP. 51
TP 50
RG. 26
RG. 25
-2589
IMP. WOODBEND 1
SASK. R.
DEVON
DISCOVERY WELL
-2500
-2550
-2600
-2650
-2700
LEGEND
CONTOURS ON TOP OF D2 ZONE
CONTOUR INTERVAL = 25 FT.
DRILLING WELL
OIL WELL
ABANDONED WELL
FEB. 15-1948

FIG. 7

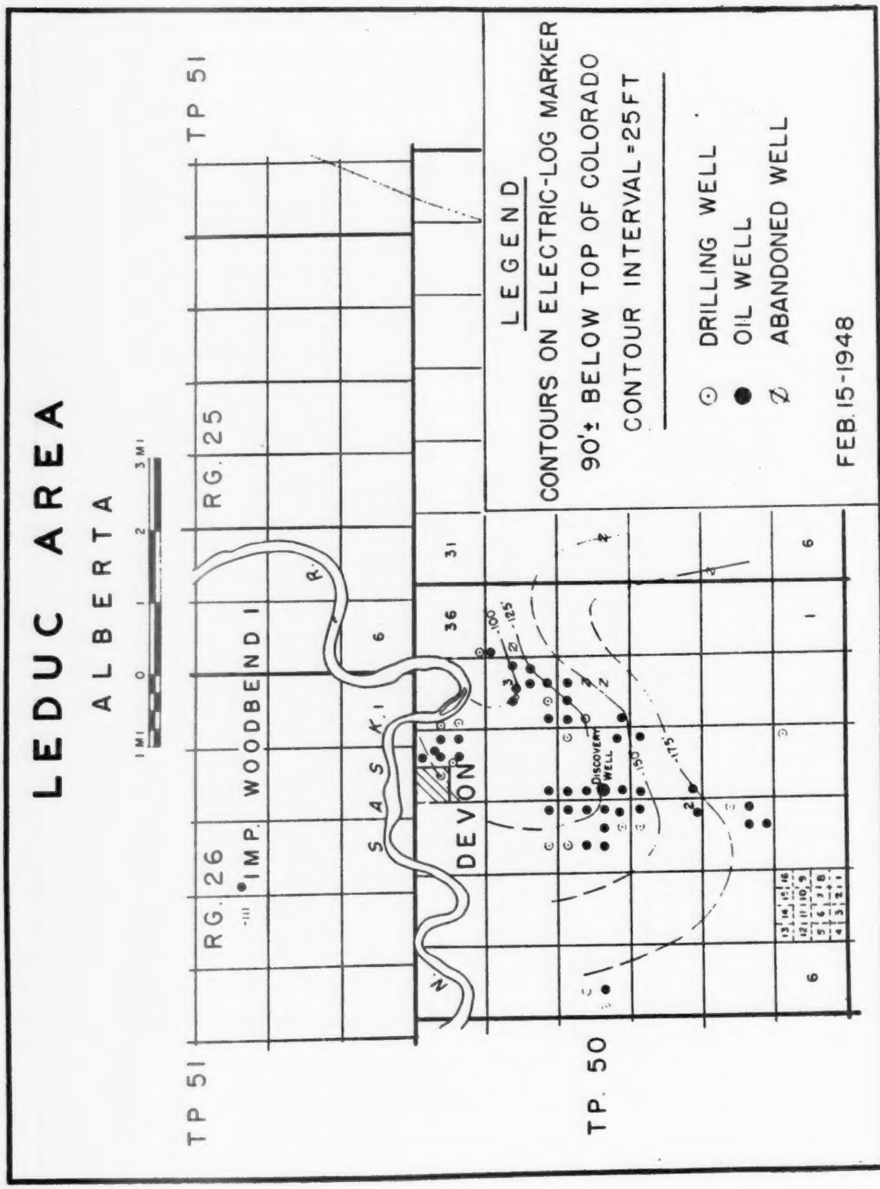

LEDUC AREA
ALBERTA
1 MI 0 1 2 3 MI
TP 51
TP 51
TP. 50
RG. 26
RG. 25
IMP. WOODBEND I
SASK. R.
DEVON
DISCOVERY WELL
-100
-125
-150
-175
LEGEND
CONTOURS ON ELECTRIC-LOG MARKER
90'± BELOW TOP OF COLORADO
CONTOUR INTERVAL = 25 FT
DRILLING WELL
OIL WELL
ABANDONED WELL
FEB. 15-1948

FIG. 8

With regard to the origin of the Leduc structure, the variable shale thicknesses overlying the D-3 reef point to differential compaction as a contributory cause of deformation in the overlying beds. Available data indicate that arching of post-D-3 Devonian beds took place gradually throughout late Devonian time and strongly indicates that differential compaction was the primary, and probably the sole, cause of this early deformation. Economically, the early development of structure was no doubt of prime importance.

Determination of causes of deformation in Cretaceous strata is complicated by the great Cretaceous-Devonian nonconformity. It is estimated that a minimum of 1,000 feet of strata was eroded from above the present Devonian top prior to Cretaceous deposition. Additional compaction of the Devonian green shale must have resulted from this load. Further compaction would not have occurred until Cretaceous strata, in excess of the amount eroded, had been deposited. No evidence exists in present data for a gradual development of structure throughout late Colorado and Lea Park time. The data do suggest the possibility of gradual structural deformation through Belly River-Edmonton time, although, because of the less regular continental type of sedimentation in the late Cretaceous, a satisfactory analysis can not be made. Surface geological mapping indicates appreciable arching of upper Edmonton beds, but because control points do not coincide with, and have a wider spread than, those from the subsurface, no accurate comparison can be made between the degree of deformation of early and late Cretaceous strata. Renewed differential compaction of the Devonian green shale would certainly have caused some arching of Cretaceous strata; whether other factors contributed is a question, but slight diastrophic uplift in late Cretaceous and Tertiary time is favored as a contributory cause of the Leduc structure.

Development and Drilling Practices

Following the completion of the Imperial's Leduc Nos. 1, 2, and 3, activity increased greatly, and by February, 1948, 20 rigs were operating in the field; 38 oil wells had been placed on production; 13 were producing from the D-2 zone, and 25 from the D-3 zone. All wells were flowing. One well had been completed as a gas well in the Viking member of the Colorado to obtain gas for drilling purposes. Five dry holes had been drilled.

In the field it is general practice to drill $13\frac{3}{8}$-inch hole to 300 feet and then cement 10 $\frac{3}{4}$-inch surface casing. The remainder of the hole, to completion depth, approximately 5,100 feet in the D-2 zone and 5,350 feet in the D-3 zone, is drilled with 9-inch rock bits, exclusive of coring. An average well requires 28 rock bits to complete in the D-2 zone, and 35 in the D-3 zone. In most wells 7-inch casing has been used for the production string and no intermediate string is required.

DRILLING PROBLEMS AND MUD CONTROL

No difficulty is experienced in controlling the deviation of the hole. Some contractors have a little trouble with caving holes in the first 2,000 feet if the

mud viscosity is not kept fairly high. The Anhydrite zone is the only formation encountered that requires the drilling mud to be chemically treated. No excessive formation pressures are present, the greatest problem being the loss of circulation encountered in drilling the D-3 zone. This occurs in both the gas cap and oil section of this zone, and several blow-outs have occurred as a result.

COMPLETION PRACTICES

Completion practices in each zone differ slightly. In the D-2 zone, where no gas cap has been found and where no water-oil contact is present in the producing wells, the practice has been to drill or core through the porous part of the zone into the dense argillaceous dolomite. Production casing is set and cemented above the porous zone, and the wells are brought into production either by swabbing or by gasifying the column of oil. Acidization of the D-2 zone has been tried in several wells, but the results have not been encouraging.

In the D-3 zone the completion procedure is slightly different, as both a gas cap and water table are present. General practice has been to drill or core to a point 15 feet above the water table, which is encountered in the Leduc field at a subsea elevation of 3,017 feet. Production casing is then run to a point 10 feet below the gas-oil contact (2,980 subsea elevation). In two wells, casing has been run through the producing zone, then perforated and acidized. The wells are placed on production from this zone either by swabbing or gasifying, a technique like that used for D-2-zone producers.

PRODUCTION

Shortly after the discovery of oil at Leduc an order setting well spacing at 40 acres was issued by the Alberta Petroleum and Natural Gas Conservation Board. Development has proceeded on this spacing, and in areas of the field where both D-2 and D-3 zones are productive twin wells are being drilled on each 40 acres.

The total production from February 13, 1947, to February 13, 1948, was 470,000 barrels. The average production at this time from 39 wells was 4,850 barrels per day.

The open-flow potential of the D-2 zone wells varies from 800 to 1,000 barrels per day, although two or three completions which have required acid treatment were of much smaller potential. In the D-3 zone open-flow potentials are considerably higher, ranging from 1,000 to 4,000 barrels per day. All open-flow potentials are measured during short-test intervals of from 2 to 8 hours.

In December, 1947, the Petroleum and Natural Gas Conservation Board issued an order, subject to revision on the basis of current reservoir-pressure measurements, restricting production to 100 barrels per day, and 150 barrels per day, for the D-2 and D-3 zones, respectively. All wells in the field produce with a normal gas-oil ratio which averages 460 cubic feet per barrel, with a separator pressure of 100 p.s.i.,[6] from the D-2 zone and 490 cubic feet per barrel, with a separator pressure of 150 p.s.i. from the D-3 zone.

[6] Pounds per square inch.

Initial production was hauled by tank truck an average of 12 miles to temporary tank-car loading facilities at Leduc. Shortly after completion of the Imperial's Leduc No. 4, plans were laid by the Imperial Oil Limited for a crude-oil gathering system and an 8-mile trunk pipe line to Nisku, the nearest rail point. Construction was started in July, and on October 29, 1947, the pipe line was in operation. From Nisku, Leduc crude at the present time is shipped by rail to refineries at Calgary, Alberta, and Regina, Saskatchewan, distances of 180 and 650 miles, respectively.

Another decision made by the Imperial Oil Limited on the successful completion of the Imperial Leduc No. 4 was to purchase and move a 6,000-barrel-per-day refinery from White Horse, Yukon Territory, to Edmonton, Alberta, a distance of 1,500 miles.

Shortage of accommodation in near-by towns for the growing number of oil-field workers, coincident with the rapid increase in activities, made it apparent that additional housing facilities were an urgent requirement. The Imperial Oil Limited purchased a quarter section of land along the south bank of the North Saskatchewan River in the most scenic part of the fertile farming country in which the field is situated. In collaboration with Housing Enterprises Limited and the Provincial Government Town Planning Commission, a model townsite has been laid out, and construction of the first 25 houses commenced in October, 1947. It was felt that the name of this new town should be expressive of the reason for its origin, and it was decided that "Devon" most aptly fulfilled this requirement.

Reservoir Characteristics

In the early development of the Leduc field, both the D-2 and D-3 zones, wherever penetrated, were cored by the Imperial Oil Limited. This coring was done by both wire-line and conventional methods, but recoveries were relatively poor, and in the fall of 1947 a program of diamond-drill coring at key locations was begun. An intensive series of laboratory projects was begun and is still continuing, accompanied by thin-section and polished-section studies. Most of the core analyses have been made by the Madison Natural Gas Company, a subsidiary of the Imperial Oil Limited, at their laboratory in Turner Valley, Alberta. The techniques are similar to those used in most core laboratories.

Effective porosities are determined in the laboratory by the United States Bureau of Mines method; permeabilities are measured to air and are expressed in millidarcys. The connate-water content is determined by using the Carter restored state technique, and the results are expressed as percentage of the void space. The following information is based on these preliminary core analyses.

In dealing with the reservoir characteristics of dolomite producing zones, it is precarious to proceed to any very conclusive answers at an early date in the development of a field. The complications in laboratory data introduced by various combinations of intercrystalline porosity, vug porosity, and open fractures, accompanied by variable deposition of secondary materials in the void spaces, result in such a confusing array of data that an over-all picture is difficult to obtain.

This is especially true in a field which has been producing for only one year. This fact is fully realized, but as a basis and introduction for future engineering papers on the Leduc field, preliminary data are here included.

A summary of the data available on the D-2 and D-3 zones of the Leduc field follows.

	D-2 Zone	*D-3 Zone*
Proved area, south of North Saskatchewan River (acres)	8,100	
Original reservoir pressure at assumed gas-oil contact (psig.)	1,760	1,894
Effective porosity (per cent)	10	13
Permeability to air (millidarcys)	25	25–500
Thickness of oil column (feet)	35	35
Connate water (per cent)	15	12
Recoverable reserves, south of North Saskatchewan River (barrels)	100,800,000	

A figure of 13 per cent porosity for the D-3 zone has been used, this being derived as an average from core-analysis results from the laboratories of the Madison Natural Gas Company, Turner Valley, Alberta, and the Carter Oil Company, Tulsa, Oklahoma, using $\frac{1}{2}$-inch-diameter plugs. This figure may be on the low side; but a higher value has not been used pending receipt of actual results from the laboratory as soon as the equipment has been adapted to a revised core-analysis technique made necessary by the extremely vuggy character of the D-3 zone cores. It is intended to make porosity and permeability determinations on D-3-zone cores by using core-samples $3\frac{3}{4}$ inches in diameter and 5 inches long. The Imperial Oil Limited plans to continue coring the D-3 zone at key locations throughout the field with a diamond-core bit, since this method has given almost 100 per cent recovery even in the vuggy dolomites of the D-3 zone. A combination of high core recovery and large laboratory specimens will, it is hoped, give as accurate a picture of a coral-reef reservoir as is obtainable.

The figures given for proved acres and recoverable reserves, as indicated, refer only to that part of the field south of the North Saskatchewan River. The Imperial's Woodbend No. 1, in Lsd. 5, Sec. 15, T. 51, R. 26, W. 4th Meridian, 3 miles northwest of the nearest producer, was completed in January, 1948, and found the D-2 zone non-productive, but oil flowed to the surface on drill-stem tests from the D-3 zone. The gas-oil contact and oil-water contact were found to be the same as in the wells at the south, and, although evidence of a generally east-west trending synclinal area is present in between, there is little doubt that the Woodbend well is a north extension discovery rather than a new field.

The oil from both zones is similar in all respects (Tables I–III). It is a paraffine-base crude, dark brown, has a low sulphur content, and possesses the best lubricating qualities of any oil found in western Canada to date. The crude in both the D-2 and D-3 zones is saturated in the reservoir, and has a shrinkage factor of approximately 0.7 and a produced gravity of 39° A.P.I. The D-2 zone oil has a solution gas-oil ratio of 660 cubic feet per barrel of stock-tank oil, and the solution gas-oil ratio for D-3 zone oil is 730 cubic feet per barrel of stock-tank oil. Results of Hempel distillation of D-3 zone oil are given in Tables I–III, oil, water, and gas analyses.

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VOL. 33, NO. 4 (APRIL, 1949), PP. 603-613, 2 FIGS.

PRE-WATERWAYS PALEOZOIC STRATIGRAPHY OF ALBERTA PLAINS[1]

J. R. McGEHEE[2]
Tulsa, Oklahoma

ABSTRACT

Detailed study based on sample determinations of 12 wells, one of which is in Saskatchewan and 11 in the plains of Alberta shows a sequence of strata of questionable age that is herein referred to as the Elk Point formation. The formation underlies a thick section of Upper Devonian strata and in turn lies on Ordovician, Cambrian, or pre-Cambrian rocks. It generally consists of two conspicuous red shales, anhydritic dolomites, and thin slightly fossiliferous argillaceous silty limestones, in addition to one to three salt members. Maximum thickness of the entire formation is 1,557 (plus or minus) feet. The age of the Elk Point formation is considered Silurian. However, recent evidence suggests at least the upper part of the formation to be Middle Devonian.

A detailed composite geological log of Elk Point area is presented.

INTRODUCTION

A thick section of Upper Devonian strata underlies the plains of Alberta and western Saskatchewan. The Waterways formation, the lowest recognized unit of the Upper Devonian, is readily recognized throughout most of the area where subsurface information exists. It lies on a sequence of strata of questionable age that is herein referred to as the Elk Point formation and this in turn lies on Ordovician, Cambrian, or pre-Cambrian rocks.

Knowledge of the pre-Waterways Paleozoic stratigraphy of the Alberta Plains has, until the period from 1944 through 1946, been limited to the sections penetrated by a few widely scattered wells. Drilling during this period added seven deep wells to this list. This paper is based on a study of 12 wells, one of which is in Saskatchewan and 11 in the plains of Alberta. The locations of these are shown in Figure 1. (Deep wells have been drilled in Saskatchewan, but samples and cores of these were not available to the writer for study.) It is the writer's purpose to summarize the section encountered below the Waterways formation in the deep tests available for study, and show the thickness, correlation, and what is known of the lateral extent of the lithologic units.

SOURCE OF DATA

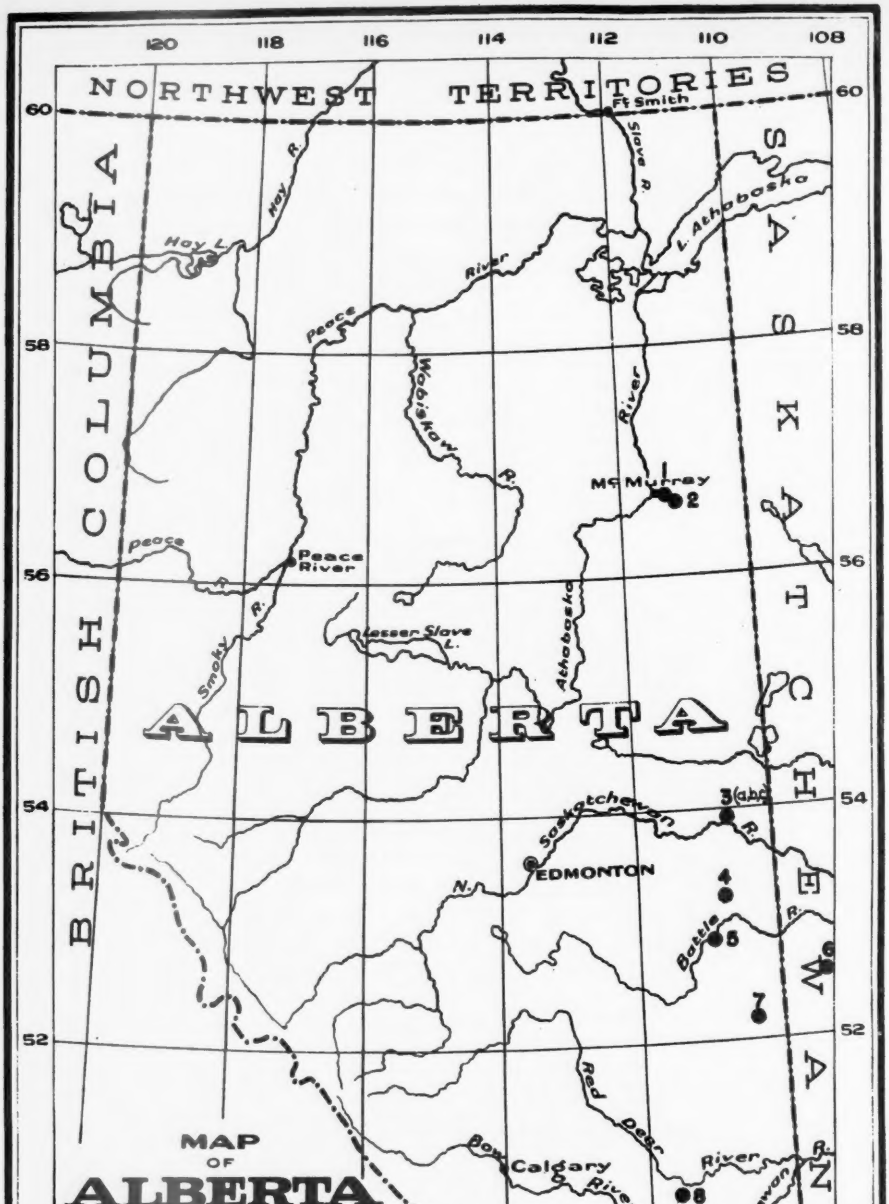
Table I lists the wells used with their respective locations.

STRATIGRAPHY AND CORRELATIONS

The north-south cross section (Fig. 2) shows the stratigraphy graphically as well as the correlations. The information on this section with the exception of

[1] Manuscript received, January 18, 1949.

[2] Shell Oil Company, Incorporated. The writer wishes to thank the various oil companies for releasing for study the samples and cores of the wells used and to acknowledge comments and suggestions of the members of the Alberta Society of Petroleum Geologists. He is particularly indebted to L. M. Clark for editing and revising the paper in the light of information disclosed by drilling subsequent to this study and for the suggestion of the term "Elk Point formation."



NORTHWEST TERRITORIES
BRITISH COLUMBIA
SASKATCHEWAN
ALBERTA
UNITED STATES
Ft Smith
Slave R.
L. Athabaska
Hay R.
Hay L.
Peace River
Wabiskaw R.
River
McMurray
2
Peace
Peace River
Smoky R.
Lesser Slave L.
Athabaska
Saskatchewan R.
N.
EDMONTON
3(a.b.c)
4
5
6
7
8
9
10
Battle R.
Red Deer River
Bow River
Calgary
S. Saskatchewan R.
Medicine Hat
Lethbridge
MAP OF ALBERTA SHOWING LOCATION OF WELLS DISCUSSED IN THIS PAPER
SCALE 1 INCH = 100 MILES
FIGURE - 1

that from Alberta Government Salt Well No. 2, which is from Allan's (1) log, represents detailed studies of the cores and samples of these wells.

One well, the Canadian Petroleums No. 2, Lsd. 1, Sec. 11, T. 85, R. 21, W. 5th Mer., which apparently penetrated pre-Waterways rocks, is not included in the cross section. Samples of this well were not examined by the writer, but I. M. Cook[3] describes red shales and anhydrite at a depth of 2,720 feet underlying Upper Devonian rocks. The writer considers these red shales and anhydrite as correlative with the rocks (Elk Point formation) encountered directly beneath the Waterways in the wells studied.

In the northernmost well of the section, the Industrial Minerals Limited Cottee No. 1, the top 492 feet consists of fossiliferous limestone interbedded with

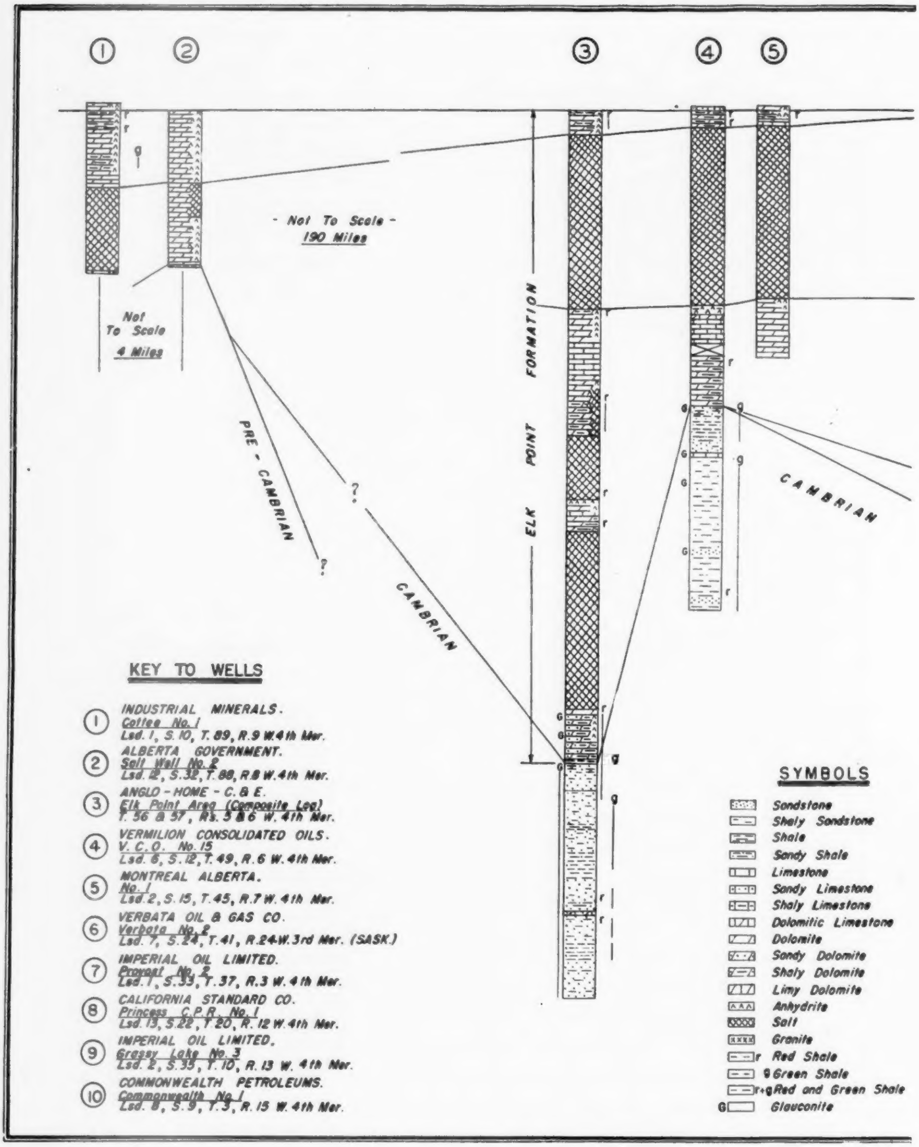
TABLE I

Name of Well	*Locations*				
	Lsd.	*Sec.*	*T.*	*R.*	*W. of Mer.*
1. Industrial Minerals Ltd., Cottee 1	1	10	89	9	4
2. Alberta Government, Salt Well 2	1	32	88	8	4
3a. Anglo-Home-C. & E., Elk Point 3	15	35	57	5	4
3b. Anglo-Home-C. & E., Elk Point 2	3	14	57	6	4
3c. Anglo-Home-C. & E., Elk Point 1	7	26	56	5	4
4. Vermilion Consolidated Oils, V. C. O. 15	6	12	49	6	4
5. Montreal Alberta No. 1	2	15	45	7	4
6. Verbata Gas & Oils Ltd., Verbata 2	7	24	41	24	3
7. Imperial Oil Limited, Provost 2	1	33	37	3	4
8. California Standard Co., Princess-C.P.R. 1	13	22	20	12	4
9. Imperial Oil Limited, Grassy Lake 3	2	35	10	13	4
10. Commonwealth Petroleum, Commonwealth 1	8	9	3	15	4

calcareous shale and shale. This series of beds has been named the Waterways formation by Warren (2) who, on the basis of a very large fauna, considers it Upper Devonian in age. Subsurface studies show that this interbedded limestone and shale series persists southward to the Montana line as a thick lithological unit generally containing what appears to be the same fauna as described by Warren from the Waterways formation.

Immediately underlying the Waterways in Cottee No. 1 is a sequence 407 feet thick consisting, in descending order, of red shale, anhydrite, dolomite, and a salt member 199 feet thick. Allan has assigned this 407-foot section to the Silurian without citing faunal evidence. There appears to be considerable justification for this correlation in view of the presence of Silurian rocks consisting of dolomites, gypsum, and salt cropping out at various localities along the western margin of the Canadian Shield. In Manitoba (3), Silurian rocks are exposed be-

[3] Personal communication.


① ② ③ ④ ⑤
- Not To Scale -
190 Miles
Not
To Scale
4 Miles
ELK POINT FORMATION
PRE - CAMBRIAN
CAMBRIAN
CAMBRIAN
KEY TO WELLS
① INDUSTRIAL MINERALS.
Cottee No. 1
Lsd. 1, S. 10, T. 89, R. 9 W. 4th Mer.
② ALBERTA GOVERNMENT.
Salt Well No. 2
Lsd. 12, S. 32, T. 88, R. 8 W. 4th Mer.
③ ANGLO - HOME - C. & E.
Elk Point Area (Composite Log)
T. 56 & 57, Rs. 5 & 6 W. 4th Mer.
④ VERMILION CONSOLIDATED OILS.
V. C. O. No. 15
Lsd. 6, S. 12, T. 49, R. 6 W. 4th Mer.
⑤ MONTREAL ALBERTA.
No. 1
Lsd. 2, S. 15, T. 45, R. 7 W. 4th Mer.
⑥ VERBATA OIL & GAS CO.
Verbata No. 2
Lsd. 7, S. 24, T. 41, R. 24 W. 3rd Mer. (SASK.)
⑦ IMPERIAL OIL LIMITED.
Provost No. 2
Lsd. 1, S. 33, T. 37, R. 3 W. 4th Mer.
⑧ CALIFORNIA STANDARD CO.
Princess C.P.R. No. 1
Lsd. 13, S. 22, T. 20, R. 12 W. 4th Mer.
⑨ IMPERIAL OIL LIMITED.
Grassy Lake No. 3
Lsd. 2, S. 35, T. 10, R. 13 W. 4th Mer.
⑩ COMMONWEALTH PETROLEUMS.
Commonwealth No. 1
Lsd. 8, S. 9, T. 3, R. 15 W. 4th Mer.
SYMBOLS
Sandstone
Shaly Sandstone
Shale
Sandy Shale
Limestone
Sandy Limestone
Shaly Limestone
Dolomitic Limestone
Dolomite
Sandy Dolomite
Shaly Dolomite
Limy Dolomite
Anhydrite
Salt
Granite
r Red Shale
g Green Shale
r+g Red and Green Shale
G Glauconite

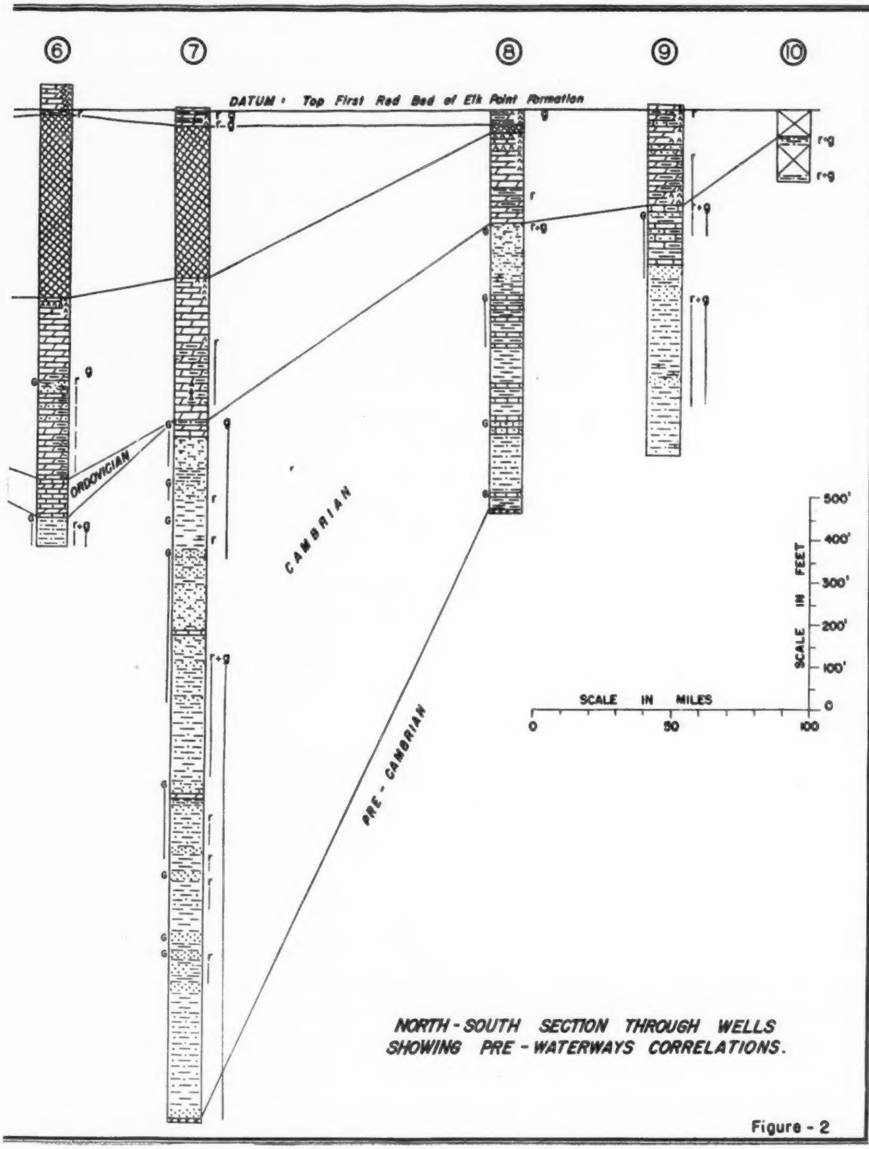

⑥
⑦
⑧
⑨
⑩
DATUM: Top First Red Bed of Elk Point Formation
ORDOVICIAN
CAMBRIAN
PRE-CAMBRIAN
SCALE IN FEET
500'
400'
300'
200'
100'
0
SCALE IN MILES
0
50
100
NORTH-SOUTH SECTION THROUGH WELLS
SHOWING PRE-WATERWAYS CORRELATIONS.

Figure - 2

tween Lake Winnipeg and Lake Manitoba along the Saskatchewan River from Grand Rapids westward to Cumberland Lake, and on the Nelson River. The rocks there consist of two dolomite members with a thick gypsum member between. Silurian rocks crop out in the vicinity of Fitzgerald and at Peace Point where they form gypsum cliffs with salt springs along the base. On the Clearwater River east of McMurray, H. D. Curry collected fossils, determined as Silurian by A. E. Wilson of the Canadian Geological Survey, from dolomites that appeared to be resting on pre-Cambrian rocks and dipping beneath the Waterways formation. This fauna, which Wilson considered "an Upper Silurian fauna suggestive of the Guelph," follows.

A pentamerid brachiopod
Conchidium sp.
Cf. *Atrypa* sp.
Coelospira sp. nr. *C. bivittata* Hall
Euomphalopterus sp.

These pre-Waterways-post-Cambrian rocks thicken southward from 407 feet in Cottee No. 1 to 1,557 feet in the Elk Point area near the North Saskatchewan River. (This sequence of strata is, for convenience, here referred to as the Elk Point formation inasmuch as the maximum known thickness of these beds is in the Elk Point area.) This thickening is largely accounted for by increase in the amount of salt which totals nearly 1,100 feet in the Elk Point wells. However, despite this thickening, the sequence is recognizable. Red shales similar to those in Cottee No. 1 underlie the Waterways limestone and overlie a thick salt member which varies little from 400 feet in thickness throughout the Elk Point-Vermilion-Wainwright-Provost-Unity areas. It is this similarity of sequence that lends confidence to the correlations from well to well and from the McMurray area to the Central Plains area of Alberta.

Southward from the Central Plains area the salt member thins. In Princess-C.P.R. No. 1 (Fig. 2, No. 8) a salt member 19 feet thick is reported with one foot of "rock salt" cored at 5,231 feet. This appears to be near the southern limit of the salt beds in the Alberta Plains inasmuch as no salt was encountered in the two southernmost wells (Fig. 2, Nos. 9 and 10).

The Elk Point formation in the northern wells consists of red and green dolomitic shales, anhydritic dolomites, and thin slightly fossiliferous argillaceous silty limestones in addition to the salt. In the southern part of Alberta, it consists of shaly mottled red and green dolomites, interbedded with anhydrite and thin dense slightly silty to argillaceous dolomites and anhydritic limestones. The commonly conspicuous red shales marking the top of the Elk Point are here represented by reddish mottled dolomite and anhydrite lying below the thick Upper Devonian marine limestone.

Table II summarizes the thickness of the Elk Point salt section with the number of members and the thicknesses penetrated in the various wells.

TABLE II

Name of Well	*Elk Point Salt* (*Feet*)	*Thickness of Entire Elk Point Formation* (*Feet*)
Cottee 1	199 (1 member)	407
Alberta Government 2	79? (1 member)	370
Elk Point 3	968 (3 members)	1,495±
Elk Point 2	1,102 (3 members)	1,495±
Elk Point 1	802 (3 members)	1,224
V. C. O. 15	425 (1 member)	714
Montreal Alberta 1	412 (1 member)	598
Verbata 2	439 (1 member)	940
Provost 2	364 (1 member)	742
Princess-C.P.R. 1	19 (1 member)	268
Grassy Lake 3	0	240
Commonwealth 1	0	64 (?)

The following is a detailed composite geological log of the Elk Point area.

DETAILED COMPOSITE GEOLOGICAL LOG OF ELK POINT AREA,
T. 56 AND 57, R. 5 AND 6, W. OF 4TH MERIDIAN

Depth in Feet	
2,705	Base of Waterways and top of Elk Point formation
-2,720	Red shale to dolomitic, anhydritic, reddish shale
-2,730	Dolomite, light brown to buff, micro-sucrose and white to brownish interbedded anhydrite
-2,740	Red shale to deep maroon and reddish brown dolomite, with anhydrite associated
-2,750	Shaly dolomite and anhydrite interbedded with traces of carnallite
-2,760	Limestone, dolomitic, gray buff, dense to lithographic with anhydrite stringers and carnallite associated
-3,180	Upper member of massive salt, with minute thin irregular stringers of dolomite and traces of reddish carnallite associated at top. Here and there thin ¼- to 1-inch greenish shale parting, also a few thin wavy dolomite stringers found in parts of cored salt interval
-3,206	Dolomite, light brown to gray brown, dense, slightly argillaceous with reddish white salt stringers and thin streaks of amber anhydrite, and thin greenish gray to brownish green, mottled, dolomitic shale associated
-3,230	Dolomite, brown to gray brown, micro-sucrose with traces of silt and thin dark brown shale partings, slightly fossiliferous in streaks (bryozoans) and minute inclusions of salt
-3,240	Limy dolomite, light brown to greenish gray, anhydritic, with thin wavy dark green shale partings, slightly fossiliferous
-3,271	Dolomitic limestone, buff gray, dense to micro-crystalline, anhydritic, fossiliferous. Seed-like forms (Charophyta), brachiopods, and crinoid stems were observed in cored limestone
-3,335	Limestone, slightly dolomitic, gray buff, finely crystalline to dense, fossiliferous (ostracods, brachiopods) with small white anhydrite stringers near top
-3,382	Dolomite, light brown to greenish gray, dense, argillaceous to shaly, slightly anhydritic at base
-3,480	Dolomite, light brown, dense and anhydrite, mottled reddish and greenish, traces of carnallite near top
-3,635	Second salt member. Massive salt with thin brownish red shaly dolomite intercalated near base
-3,647	Massive anhydrite
-3,658	Limy to calcareous dolomite, anhydritic with scattered salt inclusions and thin salt stringers, crossbedded and thinly laminated, few small ostracods at base
-3,675	Limestone, light brown, dense, slightly dolomitic, with few scattered salt inclusions

−3,702	Dolomite and shaly dolomite, deep brownish red and greenish, mottled with anhydrite and scattered small salt inclusions.
−4,135	Third salt member. Massive salt with thin silty buff micro-sucrose, dolomite stringers and interbedded anhydrite near base. Traces of carnallite
−4,262	Dolomite, micro-silty to dolomitic siltstone, anhydritic, argillaceous to shaly, brick red to brownish red with few embedded fine to coarse, rounded, frosted, and pitted sand grains. Micro-micaceous and faintly glauconitic in part
	Total composite thickness of Elk Point formation—1,557 feet
−4,327	Top of Cambrian. Sandstone, fine to coarse, rounded, frosted, and pitted grains, slightly shaly to clayey, greenish white to reddish mottled and laminated, slightly glauconitic to glauconitic, faintly arkosic near top with interbedded brick red sandy shale
−4,344	Sandstone, very fine to fine, glauconitic, gray white to brick-reddish, very finely micaceous with thin pale green to green shale laminations, slightly fossiliferous (*Dicellomus* fragments)
−4,480	Sandstone and greenish gray to green shale interbedded, very finely micaceous, glauconitic to very glauconitic, fossiliferous (scattered *Dicellomus*)
−4,529	Shale, greenish, silty, firm, fossiliferous (perfect specimens of *Dicellomus*)
−4,684	Sandstone, fine to medium, very glauconitic, reddish stained with hematitic oolite streaks, slightly fossiliferous (*Dicellomus*)
−4,727	Shale, greenish, silty laminations, glauconitic, finely micaceous, slightly fossiliferous (*Dicellomus*)
−4,750	Sandstone, very fine, medium hard, and sandy shale interbedded and crossbedded, very glauconitic (scattered *Dicellomus* fragments)
−4,821	Sandstone, white, fine to coarse. Grains are sub-angular to rounded, frosted, and pitted, trace of glauconite, ocherous stained in part. Sandstone is semi-soft to friable
	Total thickness of Cambrian—559 feet

The fossil content of the Elk Point formation is slight, the section being composed mainly of dolomite, anhydritic limestones, anhydrites, and salt, and as far as the writer is aware, no diagnostic types have been found. According to R. T. D. Wickenden,[4] a poor specimen of brachiopod was collected by him below the salt member in V. C. O. No. 15 at 3,931 feet. A. E. Wilson considered the specimen a pentamerid form and, although uncertain of identification, she believed it suggestive of a Silurian type. Scattered fossil molds of brachiopods, bryozoans, and crinoid stems, small ostracods, and small seed-like fossils resembling *Trochiliscus* have been found in some of the studies. These *Trochiliscus* forms are recorded below the first massive salt and are known from the Devonian, and if proved to be of a diagnostic type, would date the age of the salt. Peck (4) states that *Charophyta oögonia* (*Trochiliscus*) are widely distributed in the Middle and Upper Devonian of North America. The writer has considered that the preponderance of evidence indicated a Silurian age for this sequence including the salt.

However, P. S. Warren has recently disclosed new evidence regarding the age of these beds. He reports[5] having identified Middle Devonian fossils from below the first salt from cores from a well, drilled since the writer left Alberta, in Lsd. 11, Sec. 11, T. 50, R. 17, W. of 4th Meridian. If the salt referred to belongs in the Elk Point formation, this would date at least the upper part of that formation as Middle Devonian.

The base of the Elk Point section is easily detected in most places. It is

[4] Personal communication.

[5] Personal communication to L. M. Clark.

marked in each of the wells studied, by a change from red or buff dolomite of the overlying Elk Point to glauconitic sand, sandy finely micaceous shale, or reddish fossiliferous limestone of Cambrian age or the highly fossiliferous dolomitic limestone of Ordovician age. All wells, with the exception of Nos. 1, 2, 3c, and 5, encountered Cambrian rocks below the Elk Point. Cambrian probably underlies the locations of Nos. 3c and 5, but these holes were not drilled below the Elk Point. Pre-Cambrian rocks underlie the Elk Point in No. 2 and probably No. 1.

ORDOVICIAN

Ordovician rocks are exposed in the Canadian Rockies and in southern Manitoba. The principal exposures in Manitoba are along the west side of Lake Winnipeg. They are also exposed in the Little Rocky Mountains of Montana (5).

Rocks of Ordovician age are known in the subsurface only in the Unity area, but are thought by some to be present in the Milk River area (well No. 10, Fig. 2). Ordovician beds were encountered in Verbata No. 2 (No. 6, Fig. 2) in Saskatchewan. In this well a section was cored from 4,327 to 4,421 feet, consisting of 94 feet of highly fossiliferous, gray buff, dense to crystalline, slightly dolomitic limestone which contains an Ordovician fauna. The following forms were observed in the limestone by the writer: *Sowerbyella* sp., *Rafinesquina* sp., *Campylorthis* or *Strophomena* and small cup corals of the *Streptelasma* type. According to Warren,[6] who made a study of the cored fauna, "the fauna has the aspect of the Ordovician of the northern sea, which, on the basis of outcrops in areas to the east and north, may be considered Upper Ordovician or Richmond in age." This section of Ordovician apparently extends toward the east, but how far these rocks extend westward is at present unknown.

It is suggested that in part the Ordovician section logged in the Verbata test is equivalent to the exposed section in Manitoba where Dowling worked out the following sequence of Ordovician rocks in descending order: 190 feet of Stony Mountain shales; 130 feet of Upper Mottled limestone; 70 feet of Cat Head limestone; 70 feet of Lower Mottled limestone, and 100 feet of Winnipeg sandstone. These beds were considered by Dowling to be equivalents of the Galena-Trenton of Minnesota. More recently, in 1929, Foerste (6) concluded that they are possibly Richmond in age.

In the Little Rocky Mountains of Montana, the Ordovician rocks, known as the Bighorn limestone, have a thickness of 450 feet. In Commonwealth No. 1 (well No. 10, Fig. 2), there is a thin section that has been correlated by others as partly equivalent to the Bighorn in Montana. The test is the most southern shown on the cross section and the section penetrated seems to indicate post-Cambrian and pre-Devonian sediments. Unfortunately, there is a gap in the samples (5,075–5,200 feet) the writer examined. The missing interval is apparently where the operators changed the type of drilling and installed a diamond-drill for coring purposes. A steel-line measurement was reported to have been

[6] Personal communication.

made at 5,075 feet and the depth corrected to 5,140 feet, below which continuous cores were taken to 5,310 feet, total depth. According to the Alberta Conservation Board (7), the cores were found to be fossiliferous and fossils from 5,140 to 5,142 feet submitted to R. Bassler were identified as *Primitia* sp.,. and *Aparchites* sp. He thought they indicated either Ordovician or Silurian age with the probabilities more in favor of the former. Because of insufficient faunal evidence to determine otherwise, the writer believes that these beds are correlative with the Elk Point formation. Such correlation would make it correspond with the Grassy Lake well No. 3 (Fig. 2, No. 9), in which Cambrian shales are overlain by strata believed to be correlative with the Elk Point formation.

CAMBRIAN

Cambrian rocks are exposed in the Canadian Rockies of Southern Alberta and British Columbia, the Franklin Mountains in the Northwest Territories, and in the Little Rocky Mountains of Montana. Cambrian beds were encountered in eight (3a, 3b, 4, 6, 7, 8, 9, and 10) of the deep wells studied. The Cambrian is variegated in color and differs in lithologic character and thickness from place to place. It consists essentially of thin limestones, very fine sandstones or siltstones with interbedded thick green and maroon silty, finely micaceous shales. The limestones are typically finely crystalline to dense, reddish brown and mottled. They commonly contain various amounts of glauconite and are sparingly fossiliferous. The variegated sandstones and siltstones contain an abundance of glauconite whereas the shales are only slightly glauconitic. Fossils are common in these beds. The thickness varies from 684 feet in the Standard's Princess-C. P. R. No. 1 to 1,661 feet in the Imperial's Provost No. 2. In the latter well, a 15-foot bed of medium to coarse, arkosic sandstone was logged at the base of the Cambrian section. Where the entire Cambrian has been penetrated, the beds rest unconformably on pre-Cambrian igneous rocks.

Most of the Cambrian beds represented in the plains are believed to be lower Upper Cambrian in age. The identified fossils found in the Imperial's Provost No. 2 are: *Dicellomus* cf. *D. occidentalis* Bell, *Dicellomus* cf. *D. amblia* Bell, and *Linnarssonella* sp. These forms were identified by W. C. Bell[7] of the University of Minnesota, who regards them as lower Upper Cambrian in age. Similar fossils are found in the Cambrian rocks of the other wells. The writer has seen numerous other small fossil fragments in the section, but many of these are believed to be micro-fragments of trilobites which are unidentifiable. The writer has made no attempt to subdivide the Cambrian section in the plains. As shown on the north-south cross section, the Cambrian is grouped, and there is little doubt that the various sections are partly equivalent.

PRE-CAMBRIAN

Pre-Cambrian rocks are exposed in the Canadian Rockies in Alberta and British Columbia, and in the eastern and northern parts of Manitoba that form a

[7] Personal letter to E. W. Shaw of the Imperial Oil Limited.

part of the Canadian Shield. The pre-Cambrian rocks of the Alberta Rocky Mountains are largely altered sediments and lavas belonging to the Belt series, but those encountered beneath the plains are granitic in character. The pre-Cambrian has been found in wells at McMurray, Provost, and Patricia, Alberta. Samples were examined from the latter two wells: the California Standard Company's Princess-C. P. R. No. 1, and the Imperial Oil's Provost No. 2. In each, only 8–10 feet of the basement was penetrated. The rock is pinkish white granitic rock containing large feldspar crystals. Allan reports that pre-Cambrian granite was penetrated for 5 feet at McMurray in the Alberta Government's Salt Well No. 2.

CONCLUSIONS

In summary, it is believed that the red shale, salt, dolomite, and anhydrite section underlying the Waterways and overlying pre-Cambrian, Cambrian, or Ordovician rocks is one formational unit, herein named the Elk Point formation, that can be correlated throughout the area. It includes two prominent red shale markers near the top and a salt member that extends over a large part of the central Alberta Plains.

The age of the Elk Point formation is not definitely established. Silurian age is suggested by the fact that massive Silurian dolomite at Portage au Pas on the Clearwater River appears to dip beneath the Waterways beds at McMurray. It also appears that the salt springs found below Silurian gypsum near Fitzgerald occupy the same general position as the salt member of the Elk Point section at McMurray. On the other hand, paleontological evidence from cored wells is reported to suggest Middle Devonian age for the Elk Point beds. Additional paleontological evidence is needed to determine the age of these strata with certainty.

It is the writer's desire that this paper will serve as a forerunner in determining more closely the age and correlation of these beds.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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GEOLOGY OF ROCKY MOUNTAIN FRONT RANGES NEAR BOW RIVER, ALBERTA[1]

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ABSTRACT

The front ranges of the Rocky Mountains near the Bow River, Alberta, are a fine example of the thrust-fault type of structure which characterizes the eastern Canadian Rockies. The ranges consist largely of repeated sequences of Paleozoic strata dipping 40° W. and separated by subsequent valleys eroded in Mesozoic or Upper Paleozoic beds. Cambrian to Upper Cretaceous strata are exposed. The map area is traversed by the Calgary-Banff highway and the main line of the Canadian Pacific Railway and, although visited by many geologists since the 1880's, it has not heretofore been mapped.

The map area, which consists of three fault blocks that repeat most of the Paleozoic section, is bounded on the east by a major folded thrust fault which throws Middle Cambrian rocks over Upper Cretaceous strata. This fault marks the boundary between the Rocky Mountains and the Foothill belt. The Cascade Coal Basin is the westward limit of mapping. Middle Cambrian strata along the mountain front are overlain unconformably by the Ghost River formation of questionable Devonian age. This is overlain conformably by Upper Devonian dolomites and limestones and these are followed by Lower, Middle, and Upper Mississippian shales and limestones, Pennsylvanian quartzitic and dolomitic sandstones, Permian (?) chert and quartzite Triassic shaly siltstone, Jurassic black shale, and Lower Cretaceous or Jurassic sandstones, shales, and coal. No igneous rocks are exposed in this part of the Rocky Mountains.

The great thrust faults, displacements on which are measured in miles, in some places develop drag folds, but the fault planes are clean breaks with little or no gouge, and the strata on both sides approach parallelism with the fault planes.

INTRODUCTION

The front range of the Rocky Mountains of Alberta in the vicinity of the Bow River comprises an interesting geologic unit which has been visited by many geologists since McConnell's (1887) time, but heretofore has not been mapped. This area, bounded on the east by the McConnell fault marking the front of the Rockies and on the west by the faulted syncline comprising the Cascade Coal Basin, is traversed by the main transcontinental line of the Canadian Pacific Railway and the Calgary-Banff highway. It is composed of three westward-dipping fault blocks of Paleozoic strata.

AREAL GEOLOGY

The Paleozoic rocks, comprising almost the entire area mapped, occupy three

[1] Read before the Association at Denver, April 28, 1948. Manuscript received, September 27, 1948.

[2] Barnsdall Oil Company; formerly with Shell Oil Company, Inc. The writer undertook the mapping of this area out of geological curiosity and for week-end physical recreation. He had the benefit of previous geological work in this and adjacent areas, and had the pleasure and benefit of field trips in the area with P. S. Warren, G. S. Hume, H. H. Beach, C. O. Hage, M. B. B. Crockford, D. B. Layer, F. G. Lines, and others. In addition, he wishes to acknowledge certain plane-table-measured stratigraphic thicknesses furnished by N. W. Nichols and the pleasurable companionship and photographic help of Kenneth Betts, a member of the Canadian Alpine Club, who accompanied the writer on many of the field trips.

This paper, including the map and cross section, is submitted primarily for the benefit of geologists, traveling on the Calgary-Banff highway or the Canadian Pacific Railway, who are unfamiliar with the geology of this classic area and secondarily for investigators in details of the stratigraphy, paleontology, and structure.

northwest-trending blocks separated by northwest-trending thrust faults. The eastern block exhibits an unbroken section from Cambrian to Triassic, the central block a section of Upper Devonian and Mississippian rocks, and the western block a section from Cambrian to Lower Cretaceous. Upper Cretaceous strata are east of, and are overridden, by the easternmost fault which marks the Rocky Mountain front. This is referred to as the McConnell fault and is considered the sole fault of the area. The western map limit is at the Triassic contact where the Triassic dips beneath Jurassic and Lower Cretaceous strata in the Cascade Coal Basin. The areal geology is readily appreciated by inspection of the geological map (Fig. 1).

STRATIGRAPHY

CAMBRIAN

The oldest rocks in the map area consist of limestone, dolomitic limestone, and a minor amount of shale. The limestone is largely dark gray or dark brownish gray, and ranges from massive- to thin-bedded. The higher beds in part have argillaceous partings which locally give them an edgewise conglomerate appearance. Some of the limestone beds have fine irregular algae-like segregations of buff dolomite which stand out with slight relief, giving weathered surfaces a rough character.

Interbedded with this limestone are one or possibly two beds of gray almost pure calcium carbonate limestone, one of which is quarried at the Loder lime plant near Kananaskis.

Along part of the mountain front as well as in the western fault block, the contact between the Cambrian and overlying Ghost River formation appears to be conformable. The strata are steeply dipping and apparently parallel, but seen from a distance the abrupt color change to the overlying buff-weathering Ghost River beds suggests an important stratigraphic break. On close inspection, however, it is difficult to place the exact contact. In the northeastern part of the area in the vicinity of the north fork of Bowfort Creek, this is not the case. There the Ghost River and overlying Fairholme are preserved in the gently folded End Mountain syncline and in this syncline the thin-bedded Cambrian limestones are overlain with distinct angular unconformity by buff-weathering dense dolomite and green and red dolomitic shale of the Ghost River formation. Consecutively lower Cambrian limestones can be seen truncated along this unconformity (Fig. 3).

The thickness of the Cambrian is unknown as faults constitute the lower contact. However, it appears that the exposed section of Cambrian is more than 1,000 feet thick.

Trilobites were collected from two zones of the Cambrian. In the Loder lime quarry section near Kananaskis, small trilobites occur 35–40 feet below the base of the Ghost River formation in thin-bedded and lenticular-bedded dark gray limestone with yellow weathered partings. This is apparently the same fossil zone

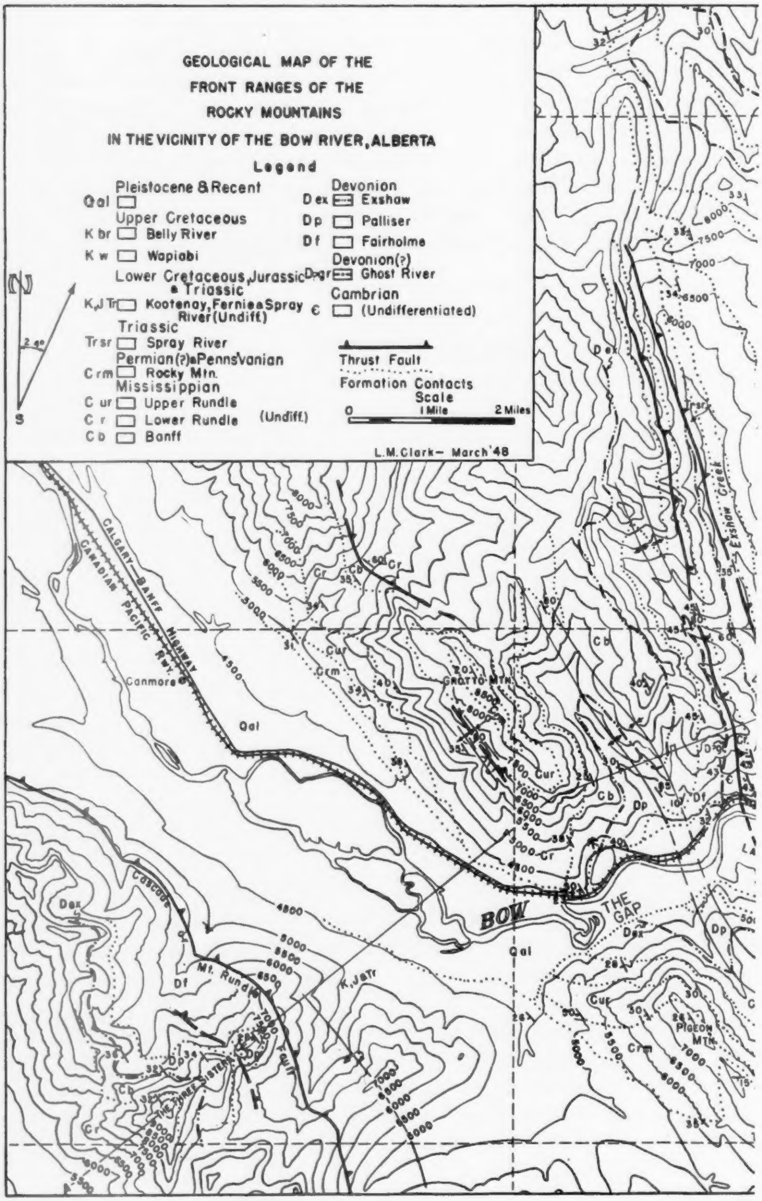
GEOLOGICAL MAP OF THE
FRONT RANGES OF THE
ROCKY MOUNTAINS
IN THE VICINITY OF THE BOW RIVER, ALBERTA
Legend
Pleistocene & Recent
Qal
Upper Cretaceous
K br Belly River
K w Wapiabi
Lower Cretaceous, Jurassic & Triassic
K,J Tr Kootenay, Fernie & Spray River (Undift.)
Triassic
Tr sr Spray River
Permian(?) & Pennsylvanian
C rm Rocky Mtn.
Mississippian
C ur Upper Rundle
C r Lower Rundle (Undiff.)
C b Banff
Devonian
D ex Exshaw
D p Palliser
D f Fairholme
Devonian(?)
D gr Ghost River
Cambrian
Є (Undifferentiated)
Thrust Fault
Formation Contacts
Scale
0 1 Mile 2 Miles
L.M.Clark- March '48
CALGARY-BANFF HIGHWAY
CANADIAN PACIFIC RAILWAY
Canmore
GROTTO MTN.
BOW
THE GAP
Mt. Rundle
THE THREE SISTERS
PIGEON MTN.
Exshaw Creek
RGE. 10

FIG. 1

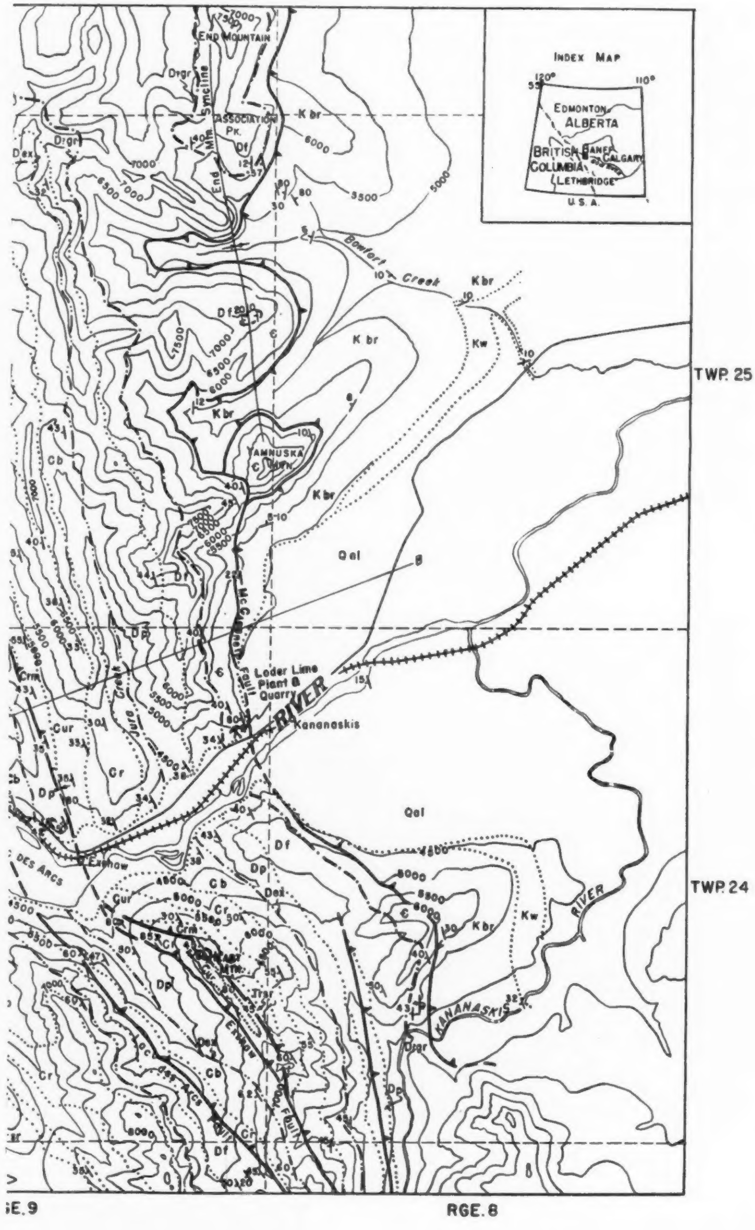
INDEX MAP
EDMONTON
ALBERTA
BRITISH COLUMBIA
BANFF
CALGARY
LETHBRIDGE
U.S.A.
END MOUNTAIN
ASSOCIATION PK.
End Mtn. Syncline
Bowfort Creek
YAMNUSKA MTN.
McConnell Fault
Loder Lime Plant & Quarry
RIVER
Kananaskis
Exshaw
KANANASKIS
RIVER
Jura Creek
Lac des Arcs Fault
Exshaw Fault
TWP. 25
TWP. 24
RGE. 8

TABLE OF FORMATIONS

System	Series	Formation	Character	Thickness (Feet)
CRETACEOUS	Upper Cretaceous	Belly River	Sandstone and shale, non-marine. Only part of formation present in map area	1,500±
		Wapiabi	Shale, black, silty to sandy, marine	1,700±
		Cardium	Quartzose sandstone and sandy shale, marine	300±
		Blackstone	Black silty shale, marine	800±
	Lower Cretaceous	Blairmore	Greenish gray sandstone and green or maroon shale, some coal and conglomerate, non-marine	2,500±
		Unconformity?		
	Lower Cretaceous?—Jurassic?	Kootenay	Sandstone, carbonaceous shale and coal, non-marine	2,000–4,500
		Unconformity		
JURASSIC	Fernie		Black shale and some fine sandstone, marine	1,100±
		Unconformity		
TRIASSIC		Spray River	Dark brown, shaly siltstone and dark brown silty shale, marine	1,000±
		Unconformity		
CARBONIFEROUS	Permian and Pennsylvanian	Rocky Mountain	Quartzite, siliceous and dolomitic fine sandstone and sandy dolomite, marine	275±
	Mississippian	Rundle	UPPER. Limestone, dolomite, black calcareous shale, red and green shale, argillaceous limestone, minor chert, marine	600±
			LOWER. Limestone, and dolomitic limestone, partly cherty, massive and cliff-forming, marine	1,100–1,300
		Banff	Black calcareous shale and argillaceous cherty limestone, marine	950–1,350
		Disconformity		
DEVONIAN	Upper Devonian	Exshaw	UPPER. Black argillaceous limestone, ocherous weathering, marine	30–40
			LOWER. Black, platy indurated shale, marine	30–50
		Palliser	Massive gray dolomitic cliff-forming limestone, marine	800–900
		Fairholme	Massive black saccharoidal dolomite with some silty to finely sandy green shale near top of formation, marine	1,300
DEVONIAN?		Ghost River	Black, gray, pink dolomite. Green and red dolomitic shale, marine?, fresh-water?	150–170
		Unconformity		
CAMBRIAN	Middle Cambrian	Cathedral?	Dark gray to black thinly bedded to massive dolomitic limestone, marine	1,000±
			Green shale with thin beds of oölitic and glauconitic limestone, marine	

FIG. 2.—Rocky Mountain front. Looking north along McConnell fault to Yamnuska Mountain from above Loder lime quarry north of Bow River. Cambrian (Є) over Belly River (BR).

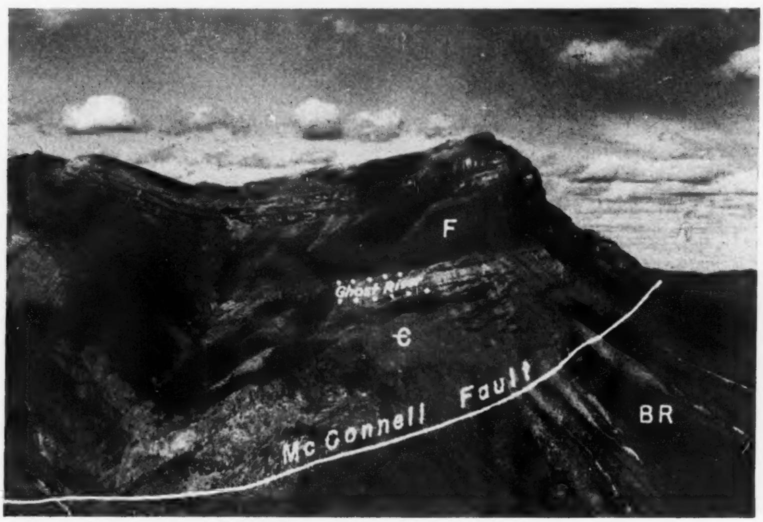

FIG. 3.—End Mountain syncline. Looking northwest along axis. Fairholme dolomite (F) lying conformably on Ghost River formation which lies with angular discordance on Cambrian limestone (Є). Note unconformity at base of Ghost River which overlaps Cambrian strata. Belly River (BR) below McConnell fault.

FIG. 4.—Mount Lorette. Looking northwest from Kananaskis River. Formations from left to right, lower Rundle limestone (LR), Banff shale (B), Exshaw shale and limestone (E), Palliser limestone (P), and Fairholme dolomite (F).

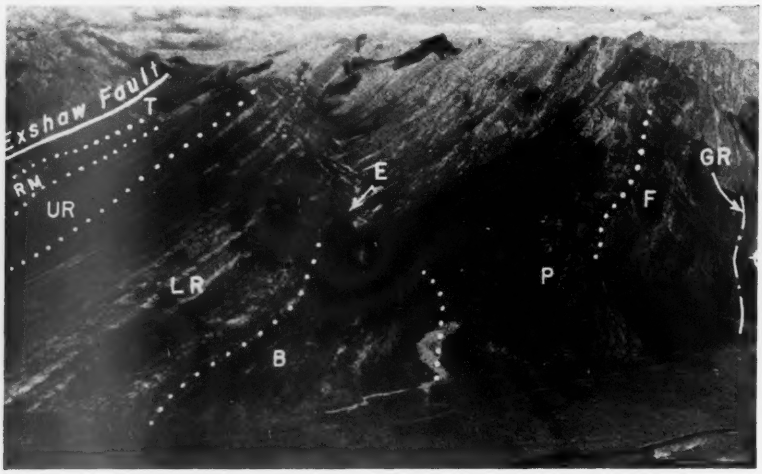

FIG. 5.—McConnell fault block. Looking north across Bow River and highway at mouth of Jura Creek. Cambrian to Triassic section exposed. Cambrian (Ꞓ), Ghost River (GR), Fairholme (F), Palliser (P), type section of Exshaw (E), Banff (B), lower Rundle (LR), upper Rundle (UR), Rocky Mountain (RM), Triassic (T).

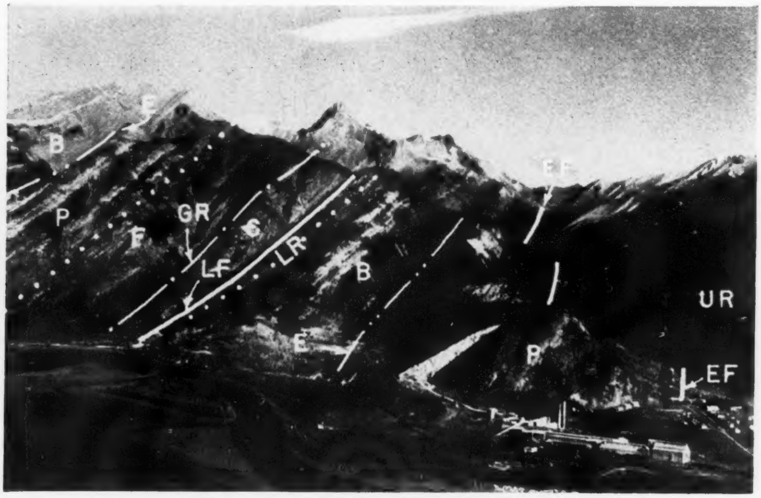

FIG. 6.—Exshaw and Lac des Arcs fault blocks. Looking northwest across Bow River at Exshaw cement plant and Exshaw canyon from Heart Mountain. Upper Rundle (UR), Exshaw fault (EF), Palliser (P), Exshaw shale and limestone (E), Banff (B), lower Rundle (LR), Lac des Arcs fault (LF), Cambrian (Є), Ghost River (GR), Fairholme (F), Palliser (P), Banff (B).

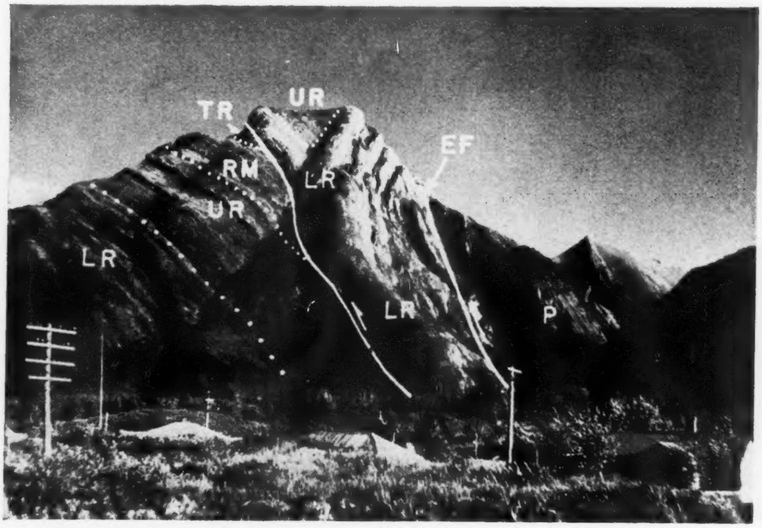

FIG. 7.—Heart Mountain. Looking southeast across Bow River from highway at Exshaw townsite. Drag fold in wedge between two branches of Exshaw fault. Lower Rundle (LR), upper Rundle (UR), Rocky Mountain (RM), Triassic (TR), Palliser (P), Exshaw fault (EF).

FIG. 8.—Exshaw fault and branch fault. Looking northwest at drainage divide between Kananaskis and Bow rivers. Lower Rundle (LR), upper Rundle (UR), Exshaw fault (EF), Palliser (P), Exshaw (E), Banff (B).

FIG. 9.—View illustrating typical Rocky Mountain structure and range development in vicinity of Banff. Looking east across Bow River from ridge to Mount Edith. Fairholme Range (F), Mount Rundle Range (R) and Sulphur Mountain Range (S). Each range is bounded on east by a thrust fault and is composed of westward-dipping Devonian and Mississippian strata. Subsequent valleys are carved in Mesozoic rocks.

from which Beach (1943, p. 9) collected trilobites, *Ehmania* sp., a form indicative of Middle Cambrian. McKinnon (unpublished University of Alberta Master of Science thesis) also apparently collected from the same zone a trilobite fauna which Deiss determined as Middle Cambrian. Beach included the fossil-bearing Cambrian limestone with the overlying Ghost River in his "Formation D," an error the writer also made before examining the Bowfort Creek section where the formations are readily differentiated because of the angular unconformity separating the Cambrian limestone from the Ghost River dolomite.

In the saddle west of Yamnuska Mountain is a small area of green shale, glauconitic and oölitic limestone, and thinly bedded fossiliferous limestone containing many trilobite fragments. This sequence is lithologically distinct from the other Cambrian rocks of the area and is interpreted as belonging to an older Cambrian formation. Walcott (1928, p. 262) describes green and purple shales and sandstone below the Middle Cambrian limestone, a few miles north opposite the mouth of Ghost River. The relationship of the green shale at Yamnuska to the Middle Cambrian limestone section is obscure, but these rocks probably represent a wedge dragged along the McConnell sole fault.

DEVONIAN?

Ghost River formation.—Overlying the Middle Cambrian limestones is a thin but distinct formation traceable throughout the map area where the base of the Fairholme is exposed. This is the Ghost River formation (Walcott, 1923). It consists of dolomitic shale, argillaceous dolomite, and dense dolomite in thin beds. The dolomitic shale is largely greenish but is partly red, maroon, pink, or variegated and the dolomite is mostly black, but includes a few red, purple, or flesh-colored beds. This sequence weathers more readily than the underlying Cambrian limestones or the overlying Fairholme dolomite and in most places forms a bench between cliffs developed in the adjacent rocks. It weathers to a distinct yellowish buff color that shows along the mountain front as a rusty band between the gray-weathering Cambrian and the black Fairholme. In most sections the upper contact is marked by a more distinct color change than the lower inasmuch as the upper limestone beds of the Cambrian also weather to a somewhat similar oxidized color (Fig. 3). This weathering of the Cambrian may partly represent pre-Ghost River weathering, and it largely accounts for the difficulty in locating the Cambrian-Ghost River contact in some sections.

The Ghost River formation varies from 150 feet to 170 feet in thickness and is fairly well exposed north of the Kananaskis River, also north of the Bow River near Kananaskis, and in the western fault block west of the Lac des Arcs fault. However, the best section is on the south end (Association Peak) of the End Mountain ridge on the east flank of End Mountain syncline. In all but the last mentioned locality, the strata are highly tilted and appear conformable and the Cambrian-Ghost River contact is not readily located unless one is thoroughly familiar with the section. On the south end of the End Mountain ridge on the

north side of the valley of Bowfort Creek, the Ghost River lies with distinct unconformity on the Cambrian limestone. At this place the Ghost River and the Fairholme strike N. 15° W. and dip 10–12° W., whereas the underlying Cambrian strata strike N. 10° W. and dip 35°–37° W. This relationship is visible along the mountain front for approximately one mile (Fig. 3). The Ghost River formation here is 154 feet thick.

No fossils were found in the Ghost River and the age is somewhat uncertain, but there is little doubt that it is more closely related to the Devonian than to the Cambrian. Although a relatively thin formation, it is present in all sections between the Fairholme dolomite and the Cambrian limestone, both along the mountain front and in the western Lac des Arcs fault block. Beach (1943, pp. 9–10) reports collecting Middle Cambrian fossils from his formation "D" which he points out seems correlative with the Ghost River, but which correlation he was reluctant to make because of certain implications. However, his description of the lithologic character indicates that he included the entire Ghost River formation together with at least 51½ feet of Cambrian limestone in his "D" formation. The upper 140½ feet of his section appears from his descriptions to belong in the Ghost River formation.

McKinnon (unpublished University of Alberta Master of Science thesis) likewise reports trilobites 195 feet below the base of the Fairholme on the ridge behind the Loder lime plant near Kananaskis. In this place also, the fossil-bearing bed is below the base of the Ghost River which is 160 feet thick as measured with plane table by N. W. Nichols, and 170 feet thick as measured by pace traverse by the writer in approximately the same section.

Walcott (1928, p. 210) and Warren (1927, p. 14) considered the Ghost River to be Devonian in age. Sloss and Laird (1947, p. 1427) found conodonts in their unit "C" in northwestern Montana, indicating the Upper Devonian age of beds which from lithologic character and similarity of stratigraphic position appear to be partly correlative with the Ghost River.

There is no doubt that the term Ghost River should be applied to the beds described in the End Mountain syncline section in view of the similarity of sequence and lithologic character, and the proximity of the section to Walcott's (1923, p. 463) type section near Ghost River. Also, doubtless, this formation is present throughout the map area although the base in most sections is not easily determined.

The End Mountain syncline section of the Ghost River formation follows. (The location of this section is on the east flank of End Mountain syncline on the south end of Association Peak, Figure 3.)

Character of Beds	*Thickness in Feet*
Overlying beds, Fairholme formation	
Covered	25
Buff-weathering dense green dolomite in beds 1–18 inches thick	12
Buff-weathering dense thin-bedded, variegated, pink or green dolomite interbedded with several 1-foot beds of red dolomitic shale	16

	Thickness in Feet
Buff-weathering, dense, gray or flesh-colored dolomite in 1–5-foot beds	20
Green and maroon indurated dolomitic shale, interbedded with ½–1-foot beds of dense, green or purplish dolomite	11
Massive, finely crystalline, purplish red dolomite	5
Dark green indurated shale, interbedded with 1–2-inch beds of yellow-weathering, dense black dolomite	10
Dark green, indurated shale	5
Yellow-weathering, dense black dolomite, interbedded with green indurated shale	20
Dark greenish gray pencillate shale	5
Buff-weathering, thinly and somewhat wavy bedded dense, dark gray dolomite	25
Total	154

Unconformity

Underlying beds, thinly bedded and somewhat lenticularly bedded black Cambrian limestone dipping 25° steeper than the overlying Ghost River

The section of the Ghost River formation on the ridge of the Loder lime quarry near Kananaskis follows (measured with plane table).

Character of Beds	*Thickness in Feet*
Overlying beds, Fairholme formation	
Covered	36
Green and red variegated dolomitic shale	10
Buff-weathering green and red mottled, thinly bedded, dense dolomite	42
Buff-weathering, dark gray to black, thinly bedded, dense dolomite	72
Oölitic limestone	⅙
Total	160

Sharply defined contact

Underlying beds, thinly bedded to fairly massive dark gray to black Cambrian limestone with irregular small yellow-weathering, finely sucrose dolomite segregations. Trilobites occur 35–40 feet below top

DEVONIAN

Fairholme formation.—Overlying the Ghost River with apparent conformity is a thick section of Upper Devonian dolomite and limestone formerly known as the Minnewanka (Shimer, 1926, p. 2) formation. Beach (1943, p. 11) proposed a two-fold division of the Minnewanka. For the lower, consisting largely of black saccharoidal dolomite, he proposed the name Fairholme formation and for the upper, the Palliser formation. Cartographically this division appears well justified and highly useful (Fig. 4).

The Fairholme is less resistant than the overlying Palliser but along the mountain front north of the Bow River it stands out as a thick, black, cliff-forming formation (Fig. 3). It is thick- to thin-bedded and although largely black saccharoidal dolomite, it includes two silty to very finely sandy green dolomitic shale members in the upper part. These are approximately 40 and 20 feet thick, respectively. Stromatoporoids and corals are abundant in the lower half but otherwise fossils are poorly preserved in this area. In the front range the formation has a thickness of 1,300 feet, measured with plane table. Warren (1947)

considers the Fairholme (lower Minnewanka) to be Upper Devonian in age, in general correlative with the Waterways formation. He reports that it contains the *Spirifer jasperensis* fauna in the western part of the Fairholme Range.

Palliser formation.—Conformably overlying the Fairholme is a gray, resistant, cliff-forming limestone known as the Palliser formation (Fig. 4). This consists largely of massive beds of uniformly dense, somewhat dolomitic limestone, dark gray to black, but weathering to a gray color. The dolomite occurs as small irregular algae-like, buff-weathering granular segregations that stand out with slight relief on weathered surfaces, giving it a very rough appearance. This resembles some of the Cambrian limestone, but is more massively bedded. The Palliser is 800–900 feet thick in this area, and is a remarkably prominent cliff-forming unit wherever observed in the Rocky Mountains from south of the Bow River to the Athabaska River northeast of Jasper.

The upper 75 feet of the Palliser is less resistant and less homogeneous than the remainder of the formation. This part consists of interbedded dolomite and limestone, several beds of which weather somewhat shaly. One or two of the dolomite beds near the top of the formation have, in places, a brecciated and vuggaceous character which appears to be due to the removal by solution of part of the original rock, probably anhydrite. The quarry of the cement plant at Exshaw is in a limestone member in the upper part of the Palliser formation.

The Palliser is partly fossiliferous and contains in its upper part the *Cyrtospirifer whitneyi* fauna, considered by Warren (1947) to be Upper Devonian in age. The highest bed is a dense black limestone containing many small crinoid stems and a large brachiopod, identified for the writer by P. S. Warren as *Cyrtospirifer kindlei* Stainbrook, a form which he states is close to *C. monticola* from the Three Forks shale of Montana.

Exshaw formation.—Overlying the Palliser with abrupt contact is black, indurated fissile, non-calcareous shale of homogeneous character, and ranging from 30 to 40 feet thick in the map area and somewhat thicker in the Mount Rundle Range. Although the break in sedimentation from limestone to black shale is sharp, no evidence was seen of erosion of the Palliser, and the two formations appear to be conformable. In places, this shale has a 1-inch bed of pyritic, phosphatic sand at the base, but in other places the black shale lies on the Palliser limestone. Its type section is in the map area in Jura Creek, where Warren (1937, pp. 454–57) described and named it the Exshaw shale. This shale erodes readily and can rarely be found cropping out, but it is overlain by a distinct ocherous-weathering black argillaceous limestone of nearly equal thickness that stands out clearly as a thin yellowish brown band in the mountain sections, especially above timber line.

Warren (1937) mentions that the cephalopod fauna which includes *Tornoceras* cf. *uniangulare* (based on which he considers the Exshaw Upper Devonian) occurs at the top of the shale. Actually this *Tornoceras*, where collected by the writer, was in the basal 2 feet of the overlying 30 feet of black argillaceous massive

limestone, this is the occurrence at both the type section and several miles north near the head of Jura Creek. The same relationship of the Exshaw shale and *Tornoceras* cf. *uniangulare* is reported by I. M. Cook (1946) from several cored wells in the southern plains of Alberta, 200 miles distant.

In view of the cephalopod fauna in the overlying argillaceous limestone and the fact that both the limestone and the shale are distinct cartographic units in the map area, as well as in the eastern part of the Rundle Range, it appears that the term Exshaw formation could well include this limestone. In this sense, it would be composed of two members: the Exshaw shale and the Exshaw limestone.

The Exshaw shale does not crop out along the Calgary-Banff highway. However, the Exshaw limestone is well exposed underlying the basal black shale member of the overlying Banff formation in the highway cut ½ mile west of the cement plant at Exshaw.

The Exshaw limestone is overlain with apparent conformity by the aforementioned black fissile clay-shale which Beach (1943, p. 17) and some others have confused with the Exshaw shale. Inasmuch as this higher shale appears to pass upward into the calcareous shales and shaly limestones of the Banff formation and in the absence of fossil evidence to the contrary, its base is tentatively the boundary between the Exshaw and Banff formations in the mapping.

MISSISSIPPIAN

Banff formation.—Overlying the Exshaw with conformity is a thick succession of calcareous shales, argillaceous limestones, and cherty limestones to which the name Banff formation was applied by Kindle (1924). In the map area, it is divisible into three members: a thick lower member consisting largely of black calcareous shale, a middle limestone member, and an upper calcareous shale member (Fig. 4). The black formation weathers brown, and, together with the Exshaw, produces a distinctive broad brown shaly band through the mountains between the adjacent gray cliff-forming limestones of the overlying Rundle and underlying Palliser formations.

The Banff thickens appreciably from east to west. In the eastern part of the map area, the thickness is 950–1,050 feet, whereas in the Rundle Range in the vicinity of the Three Sisters, it is 1,350 feet. A typical section in the eastern part of the area follows.

	Thickness in Feet
Overlying beds, Rundle formation	
Upper Shale member	
Thin- to thick-bedded, very calcareous black shale, interbedded with and grading into argillaceous black cherty limestone. In canyon sections where unweathered, this member appears to be largely limestone, but on mountain sides where longer exposed, its argillaceous character causes it to weather shaly. Highly fossiliferous, especially in upper part	200–250
Middle Limestone Member	
Massive crystalline, dark gray to black cherty limestone that weathers gray. Largely crinoid columns and containing many brachiopods and corals. In some sections, this consists of two massive limestone submembers separated by a calcareous shale submember	175–200

	Thickness in Feet
Lower Shale Member	
Thinly bedded to laminated, indurated black calcareous shale, becoming more calcareous upward. Upper part argillaceous thin-bedded limestone with nodules and beds of black chert, interbedded with black calcareous shale..	575–600

Where the entire section is not well exposed, the Middle Limestone member is easily confused with the basal beds of the Rundle, and this error has been made by some geologists. The true relations are clear in the higher parts of the mountains.

The Lower Shale member is well exposed in the highway cut ½ mile west of Exshaw, east of the Lac des Arcs fault. The entire Banff formation crosses the Bow Valley on the west side of Jura Creek, and also in the vicinity of the Gap in the western fault block; however, neither of these sections is well exposed along the highway. The highway at the Gap is cut in the Middle Limestone member. The quarry of the rock-wool plant near the Gap is in the Lower Shale member.

Warren (1927, pp. 23–27) lists fossils from two zones of the Banff formation near Banff. The lower fauna from 400 feet above the base he considers to have a definite Kinderhook aspect, and the upper from near the top of the formation, he considers to also have a Kinderhook aspect, but to include Burlington and Keokuk forms as well.

Rundle formation.—The Rundle formation (Kindle, 1924) is readily divisible, for mapping purposes, into two major divisions: a thick lower succession of massive cliff-forming limestones and an upper sequence of black, green, and minor red shales, interbedded with thick to thin limestone and dolomite beds.

Lower Rundle (*Dyson Creek formation*).—The lower Rundle is worthy of being classed as a formation rather than a member, as it persists and is recognizable throughout this part of the Rocky Mountains as well as along the foothills for more than 100 miles. It is a great cliff-forming sequence of light gray-weathering massive thick-bedded limestones and dolomitic limestones, cherty throughout, and lying with apparent conformity and gradational contact on the Banff (Figs. 4, 5, and 8). The texture varies from dense to coarsely crystalline, the basal beds being very coarsely crystalline and containing abundant crinoid columns. It is very resistant and forms the peaks of many of the highest mountains including the highest of the Three Sisters, Mount Lorette, Mount Rundle, and others. It stands out distinctly on the east face of Grotto Mountain, where it forms great light gray limestone cliffs between the brown-weathering upper Rundle capping the mountain and the Banff below. It may also be seen from the highway holding up the ridge between the lower parts of Jura and Exshaw creeks and also forming the crest of the high ridge south of the Bow River and east of Pigeon Mountain.

The lower Rundle appears to thicken on the west and within the map area varies in thickness from 1,100 to 1,300 feet.

H. H. Beach (1947) proposed the name Dyson Creek formation for this division of the Rundle.

On Tunnel Mountain at Banff, this formation is 1,590 feet thick as measured with plane table by E. P. Williams. From this part of the Rundle at Banff, Warren (1927, pp. 29–31) collected and identified faunas from three zones. The lowest, 200–500 feet above the base, Warren considers Keokuk. A second small faunule 800 feet above the base, he reports has little diagnostic value, and a third collected from beds 1,000–1,500 feet above the base, contains forms not reported above the Keokuk, but there is little evidence to determine the exact age.

Upper Rundle.—The upper Rundle, above the Dyson Creek formation, consists of thin- to fairly thick-bedded, dense to coarsely crystalline dark gray to black argillaceous fossiliferous limestone, thin quartzose sandstone, black calcareous fossiliferous shale, cherty limestone, and dolomite in the lower part. The upper part consists of massive sandy dolomite and fossiliferous limestone interbedded with green shale, one thin maroon shale, and thin cherty limestone. With the exception of the more massive dolomite and limestone beds, the upper Rundle weathers to brown rubble which at a distance resembles the weathered Banff (Fig. 8).

Beach (1947) and others who have made regional studies of the Rundle consider these two divisions of the upper Rundle as individual formations. Within the map area in the better exposed sections, the writer was able to differentiate these formations. However, as the upper Rundle is rarely well exposed and as the dips are steep and the formations comparatively thin, the two formations comprising the upper Rundle were grouped for mapping purposes.

The upper Rundle does not crop out along the Calgary-Banff highway, but it is beautifully exposed at the head of Exshaw Creek. It is also fairly well exposed ½ mile up Exshaw Creek on the east side of the canyon. There the contact with the overlying Rocky Mountain formation is exposed on the east side of Exshaw Creek 500 feet below the dam. The thickness of the upper Rundle is approximately 600 feet, of which the lowest 350 feet appear to comprise the lower division (Beach's Shunda formation).

Warren (personal communication) now considers the lower part of the upper Rundle (approximately the Shunda formation) to be Meramec in age and the upper part of the upper Rundle to be Chester. The writer collected from the lower half of the upper Rundle fossils which Warren identified as *Spirifer arkansanus*, *Productus brazerianus*, *Pentremites* sp., and *Spirifer* cf. *pellaensis*. In a limestone bed 30 feet below the Rocky Mountain formation contact, the writer collected *Spirifer pellaensis* and *Composita* cf. *subquadrata*, also identified by Warren.

Rocky Mountain formation.—Overlying the upper Rundle with apparent conformity is a sequence of massive and in places rather poorly bedded gray sandy dolomite, dolomitic and siliceous fine-grained gray sandstone, and cherty dolomitic gray quartzite that is correlated with the Rocky Mountain formation of the Banff section. This formation becomes more siliceous upward, the highest bed containing blebs of chert which give it a conglomeratic appearance. One or two zones of quartz geodes occur in the dolomitic siliceous sandstones. The upper part of the formation contains poorly preserved fossils.

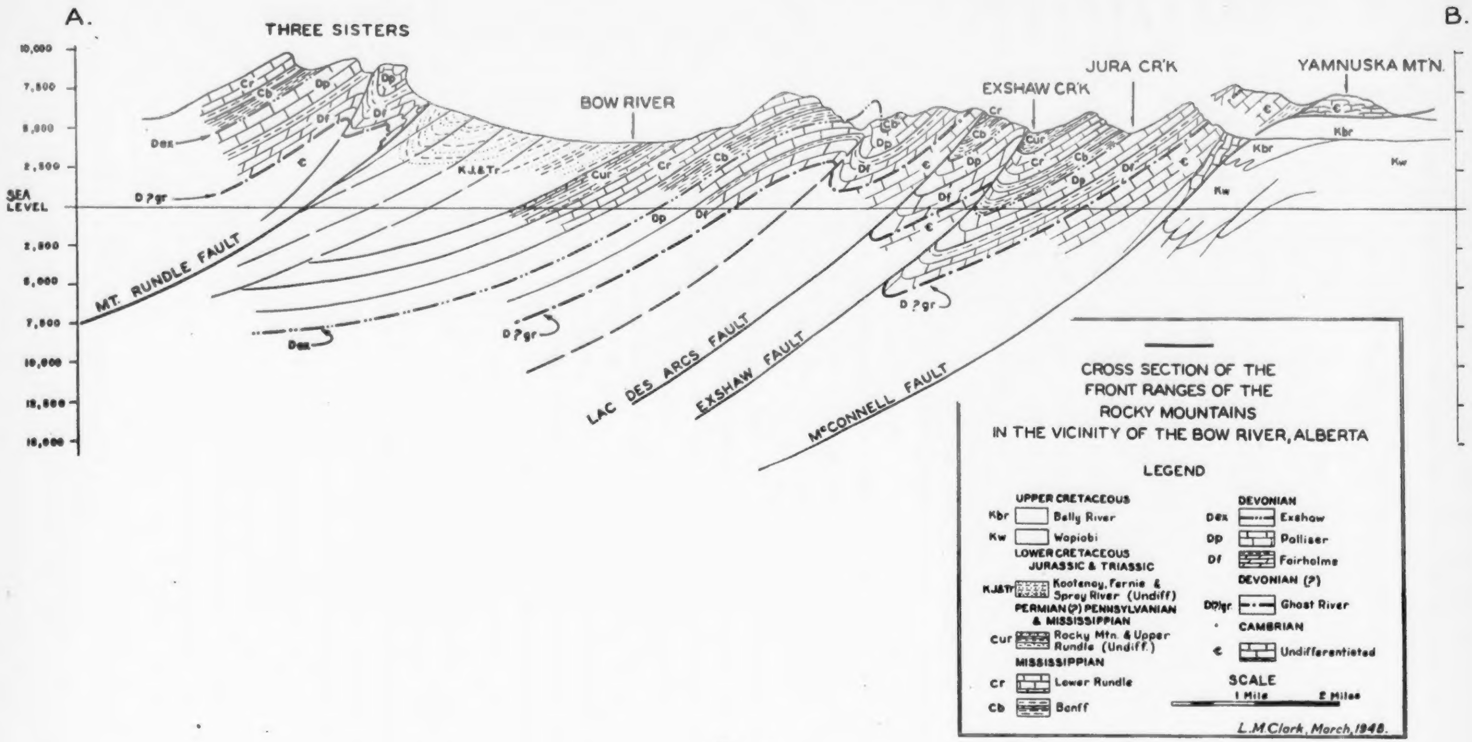
A.
B.
THREE SISTERS
BOW RIVER
EXSHAW CR'K
JURA CR'K
YAMNUSKA MTN.
10,000
7,500
5,000
2,500
SEA LEVEL
2,500
5,000
7,500
10,000
12,500
15,000
MT. RUNDLE FAULT
LAC DES ARCS FAULT
EXSHAW FAULT
McCONNELL FAULT
CROSS SECTION OF THE FRONT RANGES OF THE ROCKY MOUNTAINS IN THE VICINITY OF THE BOW RIVER, ALBERTA
LEGEND
UPPER CRETACEOUS
Kbr Belly River
Kw Wapiabi
LOWER CRETACEOUS JURASSIC & TRIASSIC
KJ&Tr Kootenay, Fernie & Spray River (Undiff)
PERMIAN (?) PENNSYLVANIAN & MISSISSIPPIAN
Cur Rocky Mtn. & Upper Rundle (Undiff.)
MISSISSIPPIAN
Cr Lower Rundle
Cb Banff
DEVONIAN
Dex Exshaw
Dp Palliser
Df Fairholme
DEVONIAN (?)
D?gr Ghost River
CAMBRIAN
Є Undifferentiated
SCALE
1 Mile
2 Miles
L. M. Clark, March, 1948.

FIG. 10

Despite its siliceous character, the Rocky Mountain formation erodes comparatively easily, well exposed sections being rare. It crops out in a narrow belt along Exshaw Creek from the vicinity of the Exshaw dam northward, and also along the western limits of the map area. It also crops out along the east side of Heart Mountain ridge south of the Bow River.

No accurate measurement of the Rocky Mountain formation was obtained, however, it appears to be 275 feet thick in this area. It is overlain by the Triassic.

Warren (personal communication) considers the lower part of the Rocky Mountain Pennsylvanian in age and the upper part Permian.

TRIASSIC

Spray River formation.—The Spray River-Rocky Mountain formation contact is the western boundary of the mapping. Within the map area the Triassic is exposed on the eastern part of Pigeon Mountain and in wedges east of the Exshaw fault in the upper part of Exshaw Canyon and along the east side of Heart Mountain. It consists of distinctive reddish brown-weathering, thinly bedded siltstone and very fine sandstone. Its contact with the underlying Rocky Mountain formation is probably sharp and disconformable, but was not observed in the area. It is overlain by Fernie (Jurassic) and Kootenay (Jurassic? Lower Cretaceous?) strata in the Cascade Coal Basin west of the map area.

STRUCTURE

The eastern part of the Rocky Mountains in the vicintiy of the Bow River is composed of a series of parallel northwest-trending ranges with peaks 8,000–10,000 feet in elevation, similar in structure, and composed largely of Paleozoic strata. Some of the ranges, for example, the Mount Rundle Range, consist of a single fault block of southwesterly dipping strata bounded on the east by a thrust fault of large displacement. Others, of which the front range under discussion is an example, are composed of several westerly dipping fault blocks that repeat part or nearly all of the Paleozoic section (Figs. 5 and 6). The strata of the various blocks dip persistently westward, mostly 30°–60°; the only exceptions are local east dips in drag folds adjacent to faults and in the comparatively minor folds here and there. The ranges are separated by deep parallel subsequent valleys eroded in the less resistant Upper Paleozoic and Mesozoic strata.

The front range in the vicinity where the Bow River emerges from the Rockies (eastern part of the Fairholme Range) is composed of three westward-dipping fault blocks which from east to west are herein referred to as the McConnell, Exshaw, and Lac des Arcs blocks. Each block is named respectively for the thrust fault which bounds it on the east. The structure is shown in the cross section (Fig. 10).

MCCONNELL FAULT AND FAULT BLOCK

The demarcation here between the Rocky Mountains and the foothills is a great thrust fault along which Cambrian rocks have been thrust over Upper

Cretaceous strata (Figs. 2 and 3). R. G. McConnell (1887, pp. 31–34) apparently was the first to recognize the significance of this structural feature, and according to Beach (1937, p. 55) this was the first recognition of a low-angle overthrust fault in western North America.

This fault, which probably dips 45° W. at the Bow River, flattens northward and is near horizontal in Yamnuska Mountain (Figs. 2 and 10). Farther north, in the upper part of Bowfort Creek, it is undulatory on a broad scale and appears to have been folded into an anticline and syncline (End Mountain syncline). McConnell (1887, pp. 33–34 and section DC) recognized this folding of the fault still farther north in the south fork of the Ghost River.

Despite the fact that the stratigraphic throw of the McConnell fault in this area is nearly 13,000 feet and the total displacement is measured in miles, there is no appreciable gouge along the fault plane. However, contortions, secondary faults, and drag folds can be observed in places in the overriding block in proximity to the fault. Recumbent folds, the axial planes of which dip steeper than the McConnell fault, occur in the incompetent Upper Cretaceous shales and sandstones of the overridden block. Also, evidence of bedding-plane slippage in the Cretaceous shales can be seen for some distance below the fault, especially where the shales are carbonaceous.

The McConnell fault, named by the writer for that sagacious and competent geologist, constitutes the sole fault of the front range; the Exshaw and Lac des Arcs faults may branch from it at depth.

The McConnell block is largely free of secondary structural features other than drag effects near the bounding faults. An asymmetric narrow drag syncline (Fig. 7) is developed in places adjacent to the Exshaw fault. North of the Bow River, this block exhibits a simple section from Cambrian to Triassic.

EXSHAW FAULT AND FAULT BLOCK

The Exshaw fault, the surface trace of which extends along the west side of Exshaw Canyon and continues southeast to the Kananaskis River, passing beneath the townsite of Exshaw and west of Heart Mountain, is a high-angle reverse fault (Figs. 6, 7, and 8). It dips 60° W. at the surface and thrusts Palliser limestone over Triassic rocks in upper Exshaw Canyon. South of the Bow River the fault splits into two branches which reunite 3 miles southeast. On the southeast the Palliser is thrust over progressively older strata, and thus the fault appears to diminish in throw in this direction. It may merge with the McConnell fault at depth.

The Exshaw block is narrow, consisting of Palliser, Exshaw, Banff, and lower Rundle strata dipping 40°–65° W. At one place a drag anticline was observed in the Palliser and at another place a drag syncline in the Rundle in this block.

LAC DES ARCS FAULT AND FAULT BLOCK

The Lac des Arcs fault, which is also a high-angle reverse fault, traverses the entire map area. It thrusts Cambrian strata over lower Rundle along 2 miles of

its trace north of the Bow River (Fig. 6), and Fairholme over Rundle along the remainder of its mapped course. Thus its throw appears to be greatest north of the Bow River, diminishing southeast and northwest. It has a westerly dip of 60°.

The Lac des Arcs block is structurally more complex than the other two. Three rather prominent asymmetric synclines and anticlines, overturned toward the east, occur in the map area. In addition, a large overturned syncline is developed west of the map area in the Cascade Coal Basin, in front of the Mount Rundle fault (Fig. 10).

This block, which is approximately 6 miles wide at the surface, exhibits stratigraphic section from Cambrian to Lower Cretaceous. The Mount Rundle fault on the west thrusts Devonian rocks over the Lower Cretaceous.

As no mapping was attempted in the Cascade Coal Basin, generalized structure data used in the construction of that part of the cross section (Fig. 10) was taken from McKay's (1935) maps. In the Mount Rundle block, only sufficient mapping was done in the vicinity of the Three Sisters to permit extension of the cross section through these peaks.

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DISCUSSION

ONLAP, OFFLAP, OVERSTEP, AND OVERLAP[1]

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Two recent articles in this Bulletin discussed the use in stratigraphy of the terms *onlap*, *overlap*, and *overstep*. Melton[3] suggested that *onlap* should refer to the "regular and progressive pinching-out of sediments above unconformities," and *strike-overlap*, "the regular truncation of sediments below unconformities." In a discussion of Melton's concepts, Lovely[4] expressed the opinion that the first situation should be termed *overlap*, and the second one *overstep*, following more or less the usage of British geologists. The present writer recently used *onlap* and *overstep*[5] and believes that American geologists should come to some agreement about the meaning of the various terms.

Melton did not refer to overstep in his original article, and his discussion of it in reply to Lovely's criticism[6] adds little to our knowledge of what he believes the term to mean as compared with *strike-overlap*. The two terms evidently are essentially synonymous if we assume that in most bodies of marine, or interfingering marine and non-marine rock, angular unconformities eventually pass downdip into disconformities, which in turn disappear farther out in the basin. *Overstep* probably is preferable to *strike-overlap* for reasons of succinctness and priority. *Overlap* seems to have been used by American geologists in the sense of both *onlap* and *overstep*, and because of such conflicting usage, abandonment of the term might be urged.

It is reasonable to suggest that a modifying term should be used for an overstep in which an unconformity, partly angular, partly parallel, is *universal* throughout a basin of deposition. To express such a situation in as simple a manner as possible, the term *complete overstep* might be used.

In the case of unconformities that occur widespread, *but not universally*, over very large parts of a craton (platform, shelf), such as one at the base of the Black River-Trenton in the Eastern Interior United States,[7] the term *regional overstep* might be employed.[8]

Onlap is reasonably a better term than *overlap* for the progressively shoreward pinching-out above unconformities of sediments of conformable sequences, because it is in contradistinction of *offlap*. *Onlap* ought not be restricted to entirely marine transgressive conditions; it should include, as well, the event in which a backland of moderate or steep

[1] Discussion received, January 8, 1949.

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[3] Frank A. Melton, "Onlap and Strike-Overlap," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 10 (October, 1947), pp. 1868–78.

[4] H. R. Lovely, Discussion, "Onlap and Strike-Overlap," *ibid.*, Vol. 32, No. 12 (December, 1948), pp. 2295–97.

[5] F. M. Swain, "Upper Jurassic of Northeastern Texas," *ibid.*, in manuscript.

[6] Frank A. Melton, in H. R. Lovely, *op. cit.*, p. 2296.

[7] John T. Galey *et al.*, "Appalachian Basin Ordovician Symposium," *Amer. Assoc. Petrol. Geol.*, Tulsa (1948), pp. 1430, 1431, 1476.

[8] Raymond C. Moore suggested (written communication) use of "complete overstep" and "regional overstep" in place of "complete overlap" and "regional overlap" as the present writer originally had suggested. Moore is not in agreement about the desirability of recognizing "regional overstep" as distinct from "complete overstep."

relief subsides, and from which is formed a nearshore or entirely terrestrial facies, in addition to an offshore facies. Within the sequence, however, the younger units extend progressively farther landward than the older units.

Offlap may result either from simple marine regression or, in the case of either a still-standing or an essentially transgressing sea, relatively rapid filling-in of the basin that pushes the shoreline seaward, that is, a delta environment.

Suggested definitions of the various terms are as follows.

1. *Onlap:* the progressive pinching-out, toward the margins of a depositional basin, of the sedimentary units of a conformable sequence of rocks. Example: onlap of the Round Mountain silt and Olcese sand by the lower Fruitvale shale, and of the latter by the Fruitvale sand, Miocene, Edison field, California.[9] Both onlap and offlap are intraformational features, perhaps are less common in stratigraphic units of higher rank. As a matter of fact, it is difficult to find published records of undoubted simple onlap or offlap.

2. *Offlap:* the progressively offshore degression of the updip terminations of the sedimentary units of a conformable sequence of rocks. Example: offlap of Tellico sandstone with respect to underlying Farragut limestone, Middle Ordovician of Tennessee.[10]

3. *Overstep:* the regular truncation of older units of a complete sedimentary sequence bý one or more later units of the sequence. The resulting unconformity may be either marginal to the basin of deposition, or within the basin as a result of local uplifts. If more than one unit rests on those beneath the unconformity, both overstep and onlap are involved. The marginal unconformities affecting deposits of a miogeosyncline[11] may occur on its cratonic margin or its eugeosynclinal[11] margin. An example of the former is the overstep of the Upper Jurassic deposits by the Lower Cretaceous, and of both of these by the Upper Cretaceous, along the cratonic northern margin of the Gulf Coast miogeosyncline. An example of the latter is the overstep of the Lower, Middle, and Upper Cambrian by the Lower Ordovician along the southeastern flank of the Appalachian geosyncline.[12]

4. *Complete overstep:* the entire blanketing with unconformable relationship of the older rocks of a basin by younger rocks. A published example that essentially represents this feature is the overlap of the Fredericksburg, Washita, Woodbine, and Eagle Ford groups by the Austin chalk in the East Texas basin.[13] Were the Austin conformable with the underlying Eagle Ford out in the basin, it would be an example of marginal overstep, but the available evidence suggests that an unconformity is present even in the middle of the basin. An objection could be raised that this basin was then simply an embayment of the Gulf Coast miogeosyncline, but there is now evidence to suggest otherwise. A second example is the completely unconformable relationship between the Proterozoic? Catoctin volcanics and the underlying Archeozoic? gneissic metasediments in southeastern Pennsylvania and adjoining Maryland.[14] *Complete overstep* might also embrace the relationship between bolson, playa, and lacustrine deposits and the underlying bedrock in intermontane basins.

[9] Everett C. Edwards, "Edison Field, California," in *Stratigraphic Type Oil Fields,* Amer. Assoc. Petrol. Geol. (1941), p. 7.

[10] C. E. Prouty, "Trenton and Sub-Trenton Stratigraphy of Northwest Belts of Virginia and Tennessee," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 32, No. 8 (August, 1948), pp. 1613, 1614.

[11] Hans Stille, "Wege und Ergebnisse der geologischtektonischen Forschung," *25 Jahre Kaiser Wilhelm Gesellsch. Ford. Wissensch.*, Bd. 2 (1936), pp. 84, 85. Marshall Kay, "Geosynclinal Nomenclature and the Craton," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 7 (July, 1947), pp. 1289–93.

[12] Frank M. Swartz, "Trenton and Sub-Trenton of Outcrop Areas in New York, Pennsylvania, and Maryland," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 32, No. 8 (August, 1948), p. 1556.

[13] Shreveport Geological Society, *Reference Report on Certain Oil and Gas Fields of North Louisiana, South Arkansas, Mississippi, and Alabama*, Pl. 11. Shreveport, Louisiana (1945).

[14] Frank M. Swartz, *op. cit.*, p. 1510.

5. *Regional overstep:* the relationship whereby a sedimentary unit rests mostly unconformably on various older rock units over a large part of a cratonic area. Examples: (1) the widespread unconformity at the base of the Black River-Trenton in the eastern United States already referred to; (2) the unconformity at the base of the Des Moines series, Pennsylvania, in the northern Mid-Continent region.[15]

[15] R. C. Moore, *Historical Geology*, 1st ed., pp. 301–303. McGraw-Hill Book Company, New York (1933).

LYONS SANDSTONE OF COLORADO FRONT RANGE[1]

JOHN C. MAHER[2]
Tulsa, Oklahoma

In his excellent paper[3] on the Lyons sandstone of the Colorado Front Range, Thompson has confined his discussion to the surface exposures of the Lyons sandstone. On this basis, he compares the Lyons sandstone with beds of Leonard or Guadalupian age in northern Colorado, western Colorado, and southern Utah, and concludes "The Lyons is probably Middle Permian and approximately equivalent to the Leonard formation of West Texas." This agrees with Reed's[4] statement, based on subsurface studies in western Nebraska, that "the top of the Cedar Hills sandstone and the top of the Lyons sandstone appear to be about the same horizon," and will meet with the general approval of subsurface geologists working in western Kansas and eastern Colorado. However, most subsurface geologists who make detailed sample logs controlled with electric logs may wonder at the doubt expressed by Thompson as to the extent of the Lyons sandstone eastward in the Denver basin. Thompson uses the distinctive cross bedding as an identifying feature of the Lyons sandstone, and this, of course, can not be recognized in well cuttings. It is possible, however, for lithologists familiar with the subsurface geology of Kansas to trace the Lyons sandstone eastward, well by well, into the sandy sequence assigned to the Cedar Hill sandstone, Salt Plains formation, and Harper sandstone, undifferentiated of the Nippewalla group of the Leonardian series in Kansas,[5] The wells useful in making this correlation eastward from exposures in Red Canyon (T. 17 S., R. 67 W.) are: Continental Oil Company's State 1 (Sec. 4, T. 18 S., R. 67 W.); Continental Oil Company's Paige 1 (Sec. 6, T. 18 S., R. 64 W.); Continental Oil Company's Young 1 (Sec. 11, T. 19 S., R. 65 W.); Skelly Oil Company's stratigraphic tests 1–6 (Ts. 26–27 S., Rs. 61–64 W.); Carter Oil Company's stratigraphic test 1 (Sec. 30, T. 26 S., R. 57 W.); Phillips Petroleum Company's Haskins 1 (Sec. 23, T. 29 S., R. 57 W.); Marland Oil Company's Mesa 1 (Sec. 8, T. 30 S., R. 50 W.); and thence following into Kansas any sequence of wells desired. Moreover, it appears from the information obtained from these wells that the Permian and Pennsylvanian boundary may be somewhat lower than the base of the Lyons sandstone where Thompson places it, and, in that case, the Fountain formation, in the subsurface at least, is part Permian in age.

[1] Discussion received, March 3, 1949. Published by permission of the director of the United States Geological Survey.

[2] Geologist, Geological Survey.

[3] Warren O. Thompson, "Lyons Sandstone of Colorado Front Range," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 33, No. 1 (January, 1949), pp. 52–72.

[4] G. E. Condra and E. C. Reed, "The Geological Section of Nebraska," *Nebraska Geol. Survey Bull. 14* (1943), p. 29.

[5] J. C. Maher, "Correlation of Paleozoic Rocks across Las Animas Arch in Baca, Las Animas, and Otero Counties, Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 30, No. 10 (October, 1946), pp. 1757–59.

———, "Subsurface Geologic Cross Section from Scott County, Kansas, to Otero County, Colorado," *Kansas Geol. Survey Prelim. Cross Sec. 4* (1947), Oil and Gas Inves. Ser.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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REVIEWS AND NEW PUBLICATIONS

PRINCIPLES OF PETROLEUM GEOLOGY, BY CECIL G. LALICKER

JOHN L. FERGUSON[1]
Tulsa, Oklahoma

Principles of Petroleum Geology, by Cecil G. Lalicker. 377+xii pp., including preface, table of contents, and index. $6\times9\frac{1}{4}$ inches. 155 figs., 67 tables, 8 pls. The Century Earth Science Series. Appleton-Century-Crofts Inc., New York. Price, $5.00.

The sorely needed and long overdue book covering the basic principles of petroleum geology and their application has finally appeared and it is well worth waiting for. Dr. Lalicker has prepared a concise work, written in terms understandable to all, with well selected and uniform illustrations, which the publishers have presented attractively, with large, easily read type, printed with good contrast on dull-finish paper. This book was published undoubtedly to fill the need for a comprehensive, up-to-date text for students of petroleum geology, and it will serve that purpose adequately. Beyond that, however, it will fill the need of executives, attorneys, engineers, landmen, production men, drillers, and other groups of scientific, technical, and practical oil men, who have increasing need for an authoritative treatment of petroleum geology, written in plain language that can be understood by laymen. Finally, it will help petroleum geologists to evaluate their field of activity more accurately.

The subject is treated in 16 chapters, covering geographic and stratigraphic distribution of petroleum, its properties, its origin and method of accumulation, reservoir rocks, development of oil-bearing structures, types of producing structures, discovery methods, recovery methods, and valuation of properties.

Emphasis is placed on types of producing structures, to which five chapters covering 160 pages of text and illustrative material, have been devoted. Ninety line drawings of uniform workmanship have been reproduced from several sources, but mainly from the publications of the American Association of Petroleum Geologists, to reveal clearly the structural relationships of these representative pools.

Stratigraphic distribution of petroleum is described at some length as an important factor in the development of petroleum accumulation. Other subjects are covered more briefly, but with sufficient detail to serve the needs of a compact coverage of the field of petroleum geology.

All new scientific publications, no matter how excellent their treatment of the subject, their text or their illustrations, have some apparent weaknesses, which give a reviewer an opportunity to suggest revisions in future editions. If this carefully prepared treatise can be said to have a general weakness it is in its provincialism. The Mid-Continent region of the United States furnishes much of the illustrative material and all other oil provinces of the world receive attention apparently in inverse ratio to their distance from Lawrence, Kansas. This is shown by Tables 2–13, which give stratigraphic sections in selected oil-producing regions, only one of which is outside the United States. Also, in the examples of oil-field structures only one field is discussed in each of the continents of South America, Asia, and two in Europe.

[1] Amerada Petroleum Corporation. Review received, February 16, 1949.

To this reviewer, the weakest chapter is on "Petroleum Discovery Methods" which seems to have been written with a historical approach using out-of-date information. Figure 116, showing changes in the dominant methods employed in petroleum exploration has been carried to 1940 only, and gives an erroneous impression of 1949 conditions. Today, oil fields are found largely by subsurface information obtained from well data or from reflection seismic data. These discovery methods should be emphasized, and the others should be mentioned briefly, where they are historically important.

Dr. Lalicker has done extraordinarily well with a difficult subject, which has so many of its basic principles shrouded in ignorance and controversy. He has brought knowledge of this rapidly evolving science up to date, and it is to be hoped that his publishers will bring out new editions at frequent intervals in order that all those interested in petroleum geology and the oil business may be kept informed.

RECENT PUBLICATIONS

ENGLAND

*"Surface Problems in the Search for Oil in Sussex," by J. W. Reeves. *Proc. Geologists' Association,* Vol. 59, Pt. 4 (London, February 17, 1949), pp. 234–69, Figs. 26–34.

FLORIDA

*"Exploration for Oil and Gas in Florida," by Herman Gunter. *Florida Geol. Survey Inf. Cir. 1* (Tallahassee, January 1, 1949). 110 multigraphed pp., 2 figs., 2 tables. 8.5×11 inches. Paper cover.

FRANCE

*"La recherche du pétrole et l'exploitation du gaz naturel dans le sud de la France," by A. Coulaty. *Bull. Assoc. Française Techniciens Petrole,* No. 73 (Paris, February 1, 1949), pp. 2–24, illus.

GENERAL

*"Can Geophysical Reflections Be Correlated with Geological Horizons?" by E. J. Handley. *Oil and Gas Jour.*, Vol. 47, No. 44 (Tulsa, March 3, 1949), pp. 84 and 87.

*"Reservoir Characteristics and Electric Logging," by Sylvain J. Pirson. *Producers Monthly,* Vol. 13, No. 4 (Bradford, Pennsylvania, February, 1949), pp. 22–28; 7 figs.

*"*A Glossary of Scientific Names,* by Stuart A. Northrop. Chiefly of fossil invertebrates. 71 pp. 4×6 inches. Private publication by Stuart A. Northrop, University of New Mexico, Albuquerque (1949). Price, $1.50.

Ira Rinehart's Yearbook, 1949. Vol. 1-Midcontinent and Texas; Vol. 2-Rocky Mountain and Southeastern States. New Field Discoveries and Oil Exploration in 22 states. Written and compiled by the staff of *Ira Rinehart's Oil Reports,* with introductory articles by national leaders of the petroleum industry. Frank J. Gardner, editor. 8.5×11 inches. Spiral binder. Published by Rinehart Oil News Company, Box 1208, Dallas, Texas. Price: to Rinehart subscribers, $10; to non-subscribers, $15.

GULF COAST

Aeromagnetic Survey of Gulf of Mexico Off Texas and Louisiana. *U. S. Geol. Survey Open Files.* Rooms 1033 (Library) and G-232, FWA Building, Washington, D. C.; Federal Building, Tulsa, Oklahoma; Room 712, City Hall, Houston, Texas; 302 West 15th Street, Austin, Texas; and office of State geologist, Baton Rouge, Louisiana, and Austin, Texas.

INDIANA

"Correlation of the Waldron and Mississinewa Formations," by R. E. Esarey and D. F. Dieberman. *Indiana Div. of Geol. Bull. 3* (Bloomington, 1949). Price, $1.00.

MARYLAND

*"Cretaceous and Tertiary Subsurface Geology," by Judson L. Anderson *et al. Maryland Dept. Geol., Mines, and Water Resources Bull. 2* (Baltimore, 1948). 456 pp., 30 figs., 39 pls., 20 tables. 6×9 inches. Clothbound. Stratigraphy, paleontology, and sedimentology of three deep test wells on the Eastern Shore of Maryland.

*"Eocene Stratigraphy and Foraminifera of the Aquia Formation," by Elaine Shifflet. *Maryland Dept., Geol., Mines, and Water Resources Bull. 3* (Baltimore, 1948). 93 pp., 18 figs., 5 pls.

OHIO

*"Petroliferous Formations in Southeastern Ohio," by Orton C. Dunn, Jr. *Oil and Gas Jour.*, Vol. 47, No. 43 (Tulsa, February 24, 1949), pp. 131–36, illus.

OREGON

"Geology of the Newport-Waldport Area, Lincoln County, Oregon," by H. E. Vokes, Hans Norbisrath, and Parke D. Snavely, Jr. *U. S. Geol. Survey Prelim. Map 88*, Oil and Gas Inves. Ser. (March 11, 1949). Sheet, 41×53 inches. Scale, 1 inch equals 1 mile. May be bought from Director, U. S. Geological Survey, Washington 25, D. C. Price, $0.75.

PENNSYLVANIA

*"The McDonald Oil Field—Allegheny and Washington Counties, Pennsylvania," by Albert I. Ingham. *Producers Monthly*, Vol. 13, No. 4 (Bradford, Pennsylvania, February, 1949), pp. 29–39; 5 figs.

TENNESSEE

*"The Geology of Nashville, Tennessee," by Charles W. Wilson, Jr. *Tennessee Div. Geology Bull. 53* (Nashville, 1948). 172 pp., 29 pls., 1 fig.

TEXAS

"Regional Geologic Map of Parts of Culberson and Hudspeth Counties, Texas," by Philip B. King. *U. S. Geol. Survey Prelim. Map 90*, Oil and Gas Inves. Ser. (1949). Sheet 40×52 inches. Scale, 1 inch equals 2.36 miles.

*"The Ellenburger Group of Central Texas," by Preston E. Cloud, Jr., and Virgil E. Barnes. *Univ. Texas Bur. Econ. Geol. Pub. 4621.* June 1, 1946 (Austin, December, 1948). 473 pp., 45 pls., 3 tables, 8 figs. Prepared in cooperation with the U. S. Geological Survey.

"Geology of the Southern Guadalupe Mountains, Texas," by P. B. King. *U. S. Geol. Survey Prof. Paper 215* (1949). 183 pp., 25 pls., 24 figs. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $3.25.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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(*Continued on page 649*)

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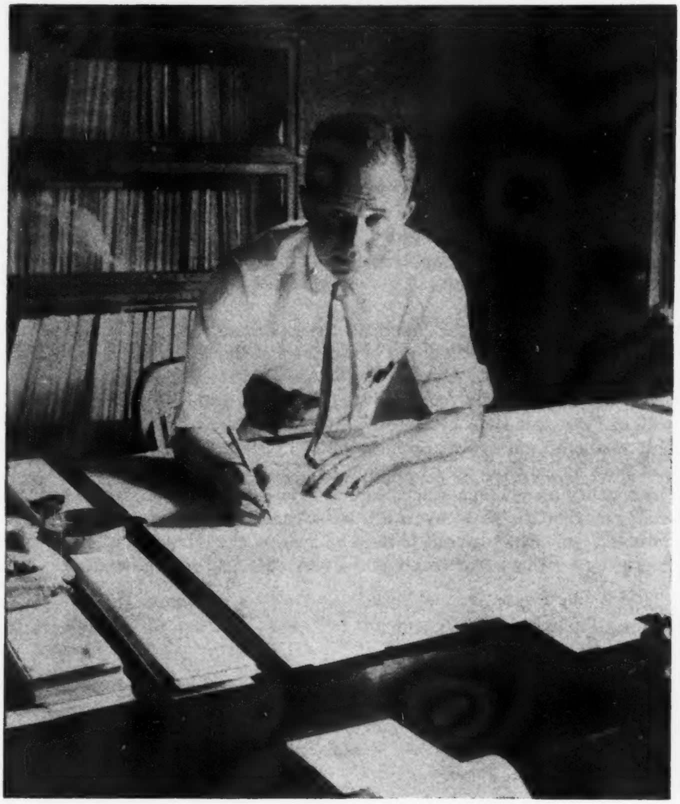
MEMORIAL

BRYAN FRANKLIN ROBINSON
(1897–1949)



On January 5, 1949, Bryan Franklin Robinson died from a heart attack in a doctor's office in Caldwell, Burleson County, Texas. On the morning of January 5, he was supervising the drilling of a well near Caldwell. Before noon on that morning he became ill and decided to drive into town and consult a doctor. He passed away shortly after arrival at the doctor's office. He was buried at Cameron, Texas, the town that he had made his home since 1929. He is survived by his wife, her two sons, his mother, and two sisters. His sisters are Mrs. LaVida Bartoo and Mrs. Helen Roland, both of Greenville, Pennsylvania.

Robbie, as he was affectionately known by his friends in the oil business, was born in

Greenville, Pennsylvania, on December 7, 1897. His father was Andrew J. Robinson and his mother's name is Clara Angermeyer Robinson. He married Mabel Stall of Ada, Oklahoma, in May 1924. At the time of this marriage Mabel Stall had two sons, Torvall L. Stall and Charles R. Stall. These boys were quite young at the time of the marriage and Robbie educated them. He must have had considerable influence on their college lives because one of them studied geology and the other studied petroleum engineering.

Robbie took his college work at the School of Mines of the University of Pittsburgh, and graduated there with a Bachelor of Science degree in 1921. During his college days he joined the Phi Gamma Delta fraternity and later became treasurer of this fraternity. While at the University of Pittsburgh, he was on the student council and also was on the student's managerial staff of the University's football team.

Soon after leaving college he came to Oklahoma and went to work for The Texas Company. In 1924 he joined the geological staff of the Twin States Oil Company with headquarters in Tulsa, Oklahoma. In 1928 he accepted a position with the Red Bank Oil Company and later became chief geologist of that company. This work brought him to Texas in 1929. In 1931 he entered independent geological work and soon thereafter became associated with H. H. Coffield of Rockdale, Texas. From this time on to the time of his death he concentrated his geological work on the area between the Mexia oil field on the north and the Luling oil field on the south. By many of his colleagues he was considered an authority on this region. Many of the faults in this area were mapped by Robbie after doing detailed surface work.

He became a member of the American Association of Petroleum Geologists in 1921. At one time he was a guide for a group of members of the A.A.P.G. over the Tanglewood fault and associated faults in Lee and Burleson counties, Texas. About the time of his death he was invited to write a paper on the Chriesman field, Burleson County, Texas, by the Bureau of Economic Geology at the University of Texas.

Robbie was a Mason and a member of the Presbyterian Church. He was a charter member of the Cameron Country Club and belonged to other social clubs in Cameron.

His personality made him a welcome guest in any group. He enjoyed hunting and fishing trips and particularly liked to travel. His pleasant disposition and his winning smile will be missed by his many friends both in and out of the oil business. The geological fraternity has lost an enthusiastic worker and a very able field geologist.

HEATH M. ROBINSON

Dallas, Texas
February, 1949

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 4 (APRIL, 1949), PP. 645-654

AT HOME AND ABROAD

NEWS OF THE PROFESSION

K. D. WHITE, who has been in the foreign service of the Standard Oil Company (New Jersey) for the past 26 years, retired effective January 1. He will continue to be active as a geological consultant specializing in foreign assignments. His residence and office address is 530 Melalenca Lane, Bay Point, Miami 38, Florida.

N. BOUTAKOFF has resigned his position of chief geologist for the Kern Trinidad Oilfields, Ltd., to become senior geologist of the Mines Department (Geological Survey Division), Treasury Gardens, Melbourne, Victoria, Australia.

H. B. STENZEL, of the Bureau of Economic Geology, Austin, Texas, presented a paper, "Use of Aerial Photographs by the Field Geologist," at a meeting of the South Texas Section of A.A.P.G., at San Antonio, February 24.

JOHN C. MAHER, United States Geological Survey, Tulsa, Oklahoma, spoke on "Pre-Pennsylvanian Geology of Southeast Colorado, Southwest Kansas, and the Oklahoma Panhandle," before the Rocky Mountain Association of Geologists, on March 1.

At the annual meeting of Alberta Association of Petroleum Geologists held at Calgary on January 19, the following officers were elected for the 1949 term: president, E. W. SHAW, Imperial Oil Limited; vice-president, JOHN G. GRAY, California Standard Oil Company; secretary-treasurer, F. A. MCKINNON, Royalite Oil Company, Ltd.; business manager, J. SPIVAK, Socony-Vacuum Exploration Company.

ROBERT MCMILLAN, vice-president of Geophoto Services, Denver, with ROBERT L. ANDERSON and JERALD ALLIGER of the same company, are in Ethiopia.

P. E. NARVARTE, consulting geophysicist, has moved his office from the Insurance Building to the American Hospital and Life Building, San Antonio, Texas. His address was carried erroneously in the February "At Home and Abroad."

W. M. FELTS, geologist with The Texas Company, spoke on "The Buried Surface of the Central Amarillo Mountains, Texas," at the meeting of the Dallas Geological Society, January 26.

BRUCE SCRAFFORD, consulting geologist, San Antonio, discussed "Developments in Southwest Texas in 1948," at the meeting of the Houston Geological Society, February 28.

WALTER H. BUCHER, professor of geology, Columbia University, New York, talked on "Fault Patterns and Fault Movements," March 7, before the Tulsa Geological Society.

HAROLD R. BILLINGSLEY, Atlantic Refining Company, Shawnee, Oklahoma, talked on "Sholem-Alechem Oil Pool, Stephens County, Oklahoma," at the luncheon meeting of the Tulsa Geological Society on March 11.

The Abilene Geological Society, Abilene, Texas, has elected the following officers for 1949: JAMES R. DAY, Pan American Production Company, president; DAVID M. GRUBBS, Drilling and Exploration Company, Inc., vice-president; and C. S. NOLAND, Skelly Oil Company, secretary-treasurer.

The officers of the New Mexico Geological Society are as follows: ROBERT E. MURPHY, president, Box 672, Roswell, New Mexico; RICHARD C. MURRAY, 1st vice-president,

Department of Geology, Stanford University, Palo Alto, California; J. P. SMITH, 2d vice-president, United States Potash Company, Inc., Carlsbad, New Mexico; GEORGES VORBE, secretary-treasurer, Department of Geology, New Mexico School of Mines, Socorro, New Mexico; VINCENT C. KELLEY, committeeman-at-large, Department of Geology, University of New Mexico, Albuquerque, New Mexico.

L. L. NETTLETON, president of the Society of Exploration Geophysicists, spoke on "Regional Gravity and Regional Geology" at the meeting of the Houston Geological Society, February 14.

Recent speakers before the Tulsa Geological Society were: D. A. MCGEE, Kerr-McGee Oil Company, Oklahoma City, "Oil in the Gulf of Mexico"; HENRY SCHAFER, Stanolind Oil and Gas Company, Tulsa, "Limestone Porosity"; A. N. MURRAY, Tulsa University, "Gilsonite Deposits in Uinta Basin"; CARL A. MOORE, University of Oklahoma, "Subsurface Faulting in McClain and Cleveland Counties, Central Oklahoma"; JOHN A. KAY, consultant, Wichita Falls, Texas, "Occurrence of Reefs in North Texas;" Walter L. AMMON, Stanolind Oil and Gas Company, Tulsa, "Pennsylvanian Reef, Lawson Area, Haskell County, Texas."

A symposium on subsurface geology and geological techniques was held in the Oklahoma Memorial Union on the campus of the University of Oklahoma at Norman, April 5 and 6. Papers were given by prominent men in the industry. Subjects covered electrical well logs, radioactivity well logging, examination of rotary drill cuttings, and caliper, temperature, and mechanical well logging. Various presidents of Oklahoma geological societies presided.

BYRON RIFE has recently been elected a director of the Holly Development Company and the company has moved to new offices at 710 Milam Building, San Antonio, Texas.

FLOYD C. DODSON, consultant of San Angelo, Texas, died, January 29, 1949, at the age of 53 years.

B. F. ROBINSON, independent operator of Cameron, Texas, died, January 5, 1949, at the age of 51 years.

FRED M. BULLARD, professor of geology at the University of Texas, is on leave of absence in order to serve as visiting professor at Vassar College, Poughkeepsie, New York, for the spring semester and at Columbia University, New York City, in the summer session. He will return to his regular teaching duties at the University of Texas, Austin, in the fall.

PAUL H. DUDLEY, district geologist for the Richfield Oil Corporation in the Los Angeles basin, has resigned to enter consulting work. His address is Box 7142, Long Beach, California.

The Pacific Section of the Association, and the Society Economic Paleontologists and Mineralogists held a joint forum on February 21, in the Auditorium of the Edison Building, 601 West 5th Street, Los Angeles. Speakers for the evening were: MANLEY L. NATLAND, Richfield Oil Corporation, "The Probable Depositional Environment of Southern California Tertiary Sediments"; PETER H. GARDETT, General Petroleum Corporation, "The Wind River Basin, Wyoming"; D. I. AXELROD, University of California, Los Angeles, "Facies Problems in Late Tertiary Continental Environments."

The Ardmore Geological Society, Ardmore, Oklahoma, met on December 15, 1948, and elected the following officers for the year 1949: President, I. CURTIS HICKS, Phillips Petroleum Company; vice-president, EARL WESTMORELAND, Seaboard Oil Company; secretary-treasurer, FRANK MILLARD, Schlumberger Well Surveying Corporation.

ROBERT N. WILLIAMS, Honolulu Oil Corporation district geologist with headquarters in Santa Barbara, has resigned to go into consulting work. Williams will have offices with the firm of Penfield and Smith, civil engineers of Santa Barbara and will do consulting work on both water and oil.

On January 13, at a meeting of the Southeastern Geological Society, the following officers for 1949 were elected: president, T. DEANE RODGERS, Stanolind Oil and Gas Company; vice-president, W. C. BLACKBURN, Humble Oil Refining Company; secretary-treasurer, ALBERT C. RAASCH, Humble Oil and Refining Company.

The Geological Society of Turkey which is now 3 years old held its semiannual meeting in Ankara, February 17–19. The 3-day session contained several interesting articles, the most important of which were the presentations on the geology of the coal district at Zonguldak, by Recep Egemen and Melih Tokay. The Zonguldak area may be said to be the Pennsylvania of Turkey. The Amasra section of the area was known during the Crimean War and was exploited during that period. The principal area at Zonguldak recently passed its 70th year of continuous operation. The officers elected for the coming year are: president, CEVAT E. TASMAN; vice-president, RECEP EGEMEN; secretary, SUAT ERK; and treasurer, KEMAL LOKMAN.

V. E. BARNES of the Bureau of Economic Geology, Austin, Texas, presented a paper on "Glen Rose and Travis Peak of Texas," at the meeting of the Shreveport Geological Society, March 7.

NORMAN D. NEWELL, professor of geology at Columbia University and curator of historical geology and fossil invertebrates at the American Museum of Natural History, is to conduct a geologic research investigation of the ancient limestone reefs in West Texas and New Mexico under the auspices of Columbia University, the American Museum of Natural History, and the Humble Oil and Refining Company. The program is designed to provide for the first time a comprehensive conception of conditions under which reef-building organisms existed and the manner in which associated limestones were formed.

CLAUDE E. ZOBELL has received an invitation to participate on a program at Brussels Belgium, on May 23–25, 1949, sponsored jointly by the Pasteur Institute, the International Union of Biological Sciences, and l'Association des Microbiologists de Langue Française, commemorating the 75th anniversary of the discovery of anaerobes (life without oxygen) by Louis Pasteur, and to receive a citation for outstanding contributions to the study of anaerobic bacteria in marine sediments with particular reference to the petroleum problem. ZoBell, who is professor of marine microbiology at the Scripps Institute of Oceanography of the University of California, is director of A.P.I. Research Project 43A, which is concerned with the part played by bacteria in the oiigin of oil.

JOHN HANOR WEBB, Phillips Petroleum Company, Bartlesville, Oklahoma, spoke to the Corpus Christi Geological Society at a luncheon meeting, February 24, on "Oil an Gas in the Folded Appalachians."

PAT KENNEDY SUTHERLAND, Phillips Petroleum Company, has been doing paleontological research at Victoria Memorial Museum, Ottawa, on fossils collected in northeastern British Columbia last summer. He will return to Canada this coming summer for Phillips and will begin work on a master's degree in the fall.

WILLIAM WYMAN MALLORY, Phillips Petroleum Company, Bartlesville, Oklahoma, spoke on "Pennsylvanian Stratigraphy and Structure, Velma Pool, Stephens County, Oklahoma," at a meeting of the Ardmore Geological Society, February 3. The talk was first given for the Oklahoma City Geological Society on December 9.

WAYNE MOORE FELTS, The Texas Company, Houston, Texas, presented a paper on January 26 at Dallas, Texas, on "Buried Surface of the Amarillo Mountains, Texas."

DON G. BENSON has been transferred from Venezuela to the Sinclair Wyoming Oil Company at Denver, Colorado.

FRANK T. CONNOLLY has left the University of Cincinnati to be employed by the Shell Oil Company, Tulsa, Oklahoma.

GEORGE H. GAUL, formerly with the Sinclair Wyoming Oil Company, is a consulting geologist at Salt Lake City, Utah.

W. W. HEATHMAN is manager of exploration in western Canada for the Union Oil Company of California at Calgary, Alberta.

WILLIAM A. NEWTON has resigned from the Carter Oil Company to become a consulting geologist at 2879 Ivanhoe Street, Denver, Colorado.

L. H. MORRIS has resigned as chief geologist for J. S. Abercrombie in Houston to enter consulting practice at San Angelo, Texas.

PHILIP ANDREWS, formerly with the Socony-Vacuum in Columbia, is with the General Petroleum Corporation at Boulder, Colorado.

CLARK A. ROACH has resigned from the Phillips Petroleum Company, Bartlesville, Oklahoma. He is geologist with Amstutz and Yates, Inc., Wichita, Kansas.

R. W. ROBBINS is assistant manager in charge of exploration for the Trigood Oil Company and Fred Goodstein's Interests, Casper, Wyoming.

W. F. ROGERS, recently with the Carter Oil Company has joined W. C. McBride, Inc., Lander, Wyoming.

RALPH E. TAYLOR is with the Humble Oil and Refining Company, Houston, Texas.

GEORGE E. UTERMOHLE, JR., is geologist with the Western Natural Gas Company, Midland, Texas.

WILLIAM V. WADE has left the Continental Oil Company to enter the employ of the Carter Oil Company at Vernal, Utah.

KARL L. WEHMEYER, JR., is resident geologist in the Bolivar coastal fields for the Mene Grande Oil Company, Maracaibo, Venezuela.

BAILEY WILLIS, professor emeritus of geology at Stanford University, died on February 20, at more than 90 years of age.

CECIL DRAKE of Taft, California, died on January 31, at the age of 49 years. He was in the employ of the Standard Oil Company of California.

BRADFORD WILLARD addressed the Lehigh University Chapter of Sigma Xi, at Bethlehem, Pennsylvania, on the Eighteenth International Geological Congress, England, 1948, which he attended.

New officers of the South Texas Geological Society are: president, PAUL B. HINYARD, district geologist, Shell Oil Company; vice-president, J. BOYD BEST, district geologist, Ohio Oil Company; secretary-treasurer, LOUIS H. HARING, JR., Stanolind Oil and Gas Company, San Antonio, Texas.

C. T. JONES, manager, foreign exploration department, Stanolind Oil and Gas Company, Tulsa, Oklahoma, is attending the Fifteenth Session, Advanced Management Program, Harvard University Graduate School of Business Administration, from February 23 to May 21.

The Geological Forum of the Pacific Section of the Association presented the following program at the University of Southern California, March 21: "San Jacinto Fault System," by D. A. McNAUGHTON; "Highlights of the Seventh Pacific Science Congress, New Zealand," by K. O. EMERY; "Kodachromes of Appalachian Features," by W. H. EASTON; and "Geology of the Eastern Portion of the Cuyama River Gorge," by THOMAS CLEMENTS.

ADDITIONAL MEMBERSHIP APPLICATIONS APPROVED

(*Continued from page 642*)

FOR ACTIVE MEMBERSHIP

Lee Charles Armstrong, Minneapolis, Minn.
P. W. Donovan, Geo. A. Thiel, Samuel S. Goldich
Frank A. Boyd, Pittsburgh, Pa.
Mason G. Walters, Fenton H. Finn, Charles H. Feldmiller
Dayton Harris Clewell, Dallas, Tex.
John T. Rouse, John W. Clark, Fred H. Wilcox
Clarence A. Cole, Shreveport, La.
B. W. Blanpied, W. C. Spooner, Claude N. Valerius
Richard Henry Jahns, Pasadena, Calif.
Ian Campbell, Merle C. Israelsky, Chester Stock
Richard Elliott, Morehouse, Lander, Wyo.
Dorr C. Skeels, Carroll E. Cook, Winthrop P. Haynes
Robert Lee Sams, New Orleans, La.
Harry X. Bay, E. M. Baxter, B. E. Bremer
John Allen Stokley, Lexington, Ky.
Daniel J. Jones, Arthur C. McFarlan, Edward G. Dobrick
Garvin Louis Tate, Grand Isle, La.
Orval W. Noland, Jacob L. Patton, Eugene A. Gibson
John Bricker Waid, Tallahassee, Fla.
Dunbar A. Fisher, W. C. Blackburn, John M. Law
Leonard Richard Wilson, Amherst, Mass.
William S. Hoffmeister, A. C. Trowbridge, W. H. Twenhofel

FOR ASSOCIATE MEMBERSHIP

Robert Wylie Anderson, Bakersfield, Calif.
Martin Van Couvering, V. L. Vander Hoof, A. I. Levorsen
James Sadler Baker, Plainfield, N. J.
A. C. Trowbridge, N. E. Baker, Geo. E. Dorsey
Robert Webster Berry, San Antonio, Tex.
Charles E. Decker, V. E. Monnett, Keith M. Hussey
William David Bradford, Casper, Wyo.
Donald E. Edstrom, H. E. Summerford, H. E. Barton
John Edward Coppinger, Lubbock, Tex.
Raymond Sidwell, Charles A. Renfroe, Leroy T. Patton
James Stubbs Critz, Houston, Texas
Wayne V. Jones, James H. McGuirt, James L. Ballard

Hal Stone Dean, Palo Alto, Calif.
V. L. Vander Hoof, A. I. Levorsen, Siemon Wm. Muller
Robert Huey Dickey, Worland, Wyo.
Loris J. Fulton, Robert A. Fellows, Geo. A. Thiel
Declan Phillip Ford, Bakersfield, Calif.
W. D. Cortright, Cordell Durrell, Irvine E. Stewart
Joseph Herman Goth, Jr., Denver, Colo.
R. E. Sherrill, A. I. Ingham, C. E. Prouty
Eugene Greenwood, Fort Worth, Tex.
Clarence M. Sale, W. M. Winton, Leo Hendricks
Thomas Andrew Gwynn, Vaughn, Mont.
Geo. H. Hansen, Harold J. Bissell, R. H. Beckwith
William Arnold Halamicek, Jr., Lubbock, Tex.
Charles A. Renfroe, Leroy T. Patton, W. I. Robinson
Earl P. Hale, Harvey, La.
Keith M. Hussey, Carl A. Moore, E. L. Lucas
Leonard C. Halpenny, Tucson, Ariz.
A. Nelson Sayre, S. W. Lohman, Silas C. Brown
Arthur Scott Hawley, Bakersfield, Calif.
John H. Beach, L. W. Saunders, Thomas J. Fitzgerald
Raymond Beryl Hayes, Baton Rouge, La.
Grover E. Murray, R. A. Steinmayer, F. E. Turner
Clarence Wayne Hughes, Lubbock, Tex.
Raymond Sidwell, Charles A. Renfroe, W. I. Robinson
Harland Brasher Hundley, Baton Rouge, La.
Richard Joel Russell, H. V. Howe, Grover E. Murray
William Carl Irvin, Lubbock, Tex.
Raymond Sidwell, Charles A. Renfroe, W. I. Robinson
Charles R. Kolb, Baton Rouge, La.
Grover E. Murray, Richard J. Russell, H. V. Howe
Stuart A. Levinson, St. Louis, Mo.
Betty Kellett Nadeau, Norman S. Hinchey, Dorothy Jung Echols
Wayne Hamilton Mack, Oklahoma City, Okla.
E. F. Schramm, Walter L. Moreman, F. E. Wimbish
Thomas Paul McCann, Boulder, Colo.
Warren O. Thompson, A. E. Brainerd, Don B. Gould
Albert Kenneth McFarland, Denver, Colo.
Sam Zimmerman, George R. Downs, Lee H. Cornelius
John Andrew McGinley, Oklahoma City, Okla.
Harold J. Kleen, F. L. Whitney, Fred M. Bullard
Edith Merritt McKee, Houston, Tex.
Robert H. Nanz, Jr., Ed A. Vogler, S. W. Lowman
Park Greenman Ogden, Jr., Lake Charles, La.
Wenzel B. Neill, Frank A. Bruner, H. Mack Cox
Frank Hugh Olson, Midland, Tex.
L. A. Nelson, M. H. Steig, Addison Young
Margaret Ann Parker, Urbana, Ill.
Alfred H. Bell, L. E. Workman, David H. Swann
Ashton Turner Perry, Jr., College Station, Tex.
S. A. Lynch, Frederick R. Burt, William C. Rasmussen
John Leighton Read, Jr., Norman, Oklahoma
L. W. Clark, E. L. Lucas, V. E. Monnett

David D. Riveroll, Los Angeles, Calif.
J. M. Hamill, Boris Laiming, Paul P. Goudkoff
Virginia Mae Rutledge, Bartlesville, Okla.
V. E. Monnett, Keith M. Hussey, Charles E. Decker
John William Skinner, Jr., College Station, Tex.
S. A. Lynch, Frederick A. Burt, W. H. Alexander, Jr.
Avery Edward Smith, Norman, Okla.
V. E. Monnett, E. L. Lucas, Carl A. Moore
Jean Elizabeth Soady, Casper, Wyo.
H. E. Summerford, Wilbert S. Larson, Jr., Jed B. Maebius
Royal Bernard Strong, Grand Rapids, Mich.
K. A. Ackley, R. M. English, Wade W. Turnbull
John Gooch Troster, Stanford University, Calif.
Siemon Wm. Muller, A. I. Levorsen, A. C. Waters
Elmer Dean Umbach, Casper, Wyo.
Theo. A. Link, D. L. Blackstone, Jr., Wm. H. Curry
Lewis Coy Warren, Midland, Tex.
Charles F. Henderson, L. C. Lindeblad, L. S. Melzer
Virginia Ada Warren, Paso Robles, Calif.
Lowell R. Laudon, M. L. Thompson, Harold R. Wanless
Robert Wesselhoeft, Jr., Abilene, Tex.
John P. Byram, David M. Grubbs, Frank B. Conselman
Joseph Dunstan Mitchell Williamson, New Orleans, La.
D. N. Rockwood, R. A. Steinmayer, John C. McCampbell

FOR TRANSFER TO ACTIVE MEMBERSHIP

Maxwell Gary Capen, Bakersfield, Calif.
W. D. Kleinpell, John D. Hale, Thomas J. Fitzgerald
Lawrence Carey Craig, Grand Junction, Colo.
Richard P. Fischer, Marshall Kay, H. N. Coryell
John Henry Fackler, Paso Robles, Calif.
T. A. Baldwin, J. E. Kilkenny, H. F. Ashauer
Elvin Millard Hurlbut, Jr., Tyler, Tex.
H. M. Fritts, H. M. Goodman, H. B. Stenzel
Darrel L. Kirkpatrick, Bakersfield, Calif.
John E. Kilkenny, Lesh C. Forrest, John D. Hale
William Gibson McCampbell, Jr., Tallahassee, Fla.
Dunbar A. Fisher, W. C. Blackburn, John M. Law
Frederick Paul Schweers, Ardmore, Okla.
Jerome Westheimer, M. P. White, C. W. Tomlinson
Harry Oscar Tilleux, Shreveport, La.
C. D. Stephenson, L. D. Bartell, W. E. Belt, Jr.

NATIONAL RESPONSIBILITY OF GEOLOGISTS

The Association committee on national responsibility of geologists is attempting to get the complete roster of all A.A.P.G. members who are in the reserves of any of the armed forces. Any member who has not received one of the questionnaires is requested to write for one to A.A.P.G. Headquarters, Box 979, Tulsa 1, Oklahoma. The questionnaire is reproduced on the following page.

COPY OF QUESTIONNAIRE ON MILITARY EXPERIENCE

To Members and Associates and Associates in the Armed Forces:

The records at A.A.P.G. Headquarters show that you served in the armed forces of the U.S.A. during World War II. It is the desire of the committee on National Responsibility of Geologists to learn the present status of all those who so served in order that plans may be made for more effective utilization of geological and other scientific talent in the armed forces.

To assist us in this compilation will you please fill out the following form and return in duplicate to the A.A.P.G., Box 979, Tulsa 1, Oklahoma. A copy of this form is enclosed for your own files.

SERVICE IN WORLD WAR II

1. Check appropriate block:

☐ Air Force ☐ Army ☐ Navy ☐ Marines

☐ Coast Guard ☐ Other____________
(Specify)

2. Arm or service within 1 above:____________

3. Dates of entry and release from service:____________ ____________
(Entry) (Release)

4. Rank at time of discharge or separation:____________

5. Serial or service number:____________

6. Brief description of type and kind of duties performed during your service (if more space needed, use back of this sheet, or another sheet):____________

PRESENT STATUS

7. Are you a member of any armed forces reserves?

☐ Yes ____________ ____________ ☐ No
(Branch) (Service)

8. ☐ Active status ☐ Inactive status

9. ☐ Organized unit ☐ Unassigned

10. Present occupation:____________

11. Business address:____________

Date submitted____________ Signature____________

Name typed____________

FIELD CONFERENCE IN POWDER RIVER BASIN, WYOMING, AUGUST 9–13, 1949

The Wyoming Geological Association fourth annual field conference will be held in the Powder River Basin, Wyoming, from August 9 to 13. Registration will begin at 4:00 P.M., Tuesday, August 9, at the conference headquarters in the Sheridan Inn, Sheridan, Wyoming.

Field trips will be by automobile out of Sheridan on August 10 and 11, and from Sheridan to Casper on August 12. These will permit examination and discussion of the stratigraphic section from pre-Cambrian to Eocene, the structural features, and the pro-

ducing fields on the west side of the Powder River Basin, along the east front of the Big Horn Mountains. Lectures are scheduled for evening meetings at Sheridan.

On Saturday, August 13, aerial reconnaissance trips are scheduled. Each flight will be from Casper north over Salt Creek to Sheridan, thence southeast across the Powder River Basin and along the east flank to Mush Creek, south to Lance Creek, and west to Casper. The distance is about 500 miles, the time about 3 hours. All planes will be commercial airline DC-3's. Automobile trips are planned out of Casper on August 13, for those who prefer not to fly.

The conference guidebook will include logs of all the principal roads of the Powder River Basin and illustrated articles on stratigraphy, structure, oil and gas fields, and other features of geologic interest. Authors contributing to the guidebook include geologists of the Wyoming Geological Association, the University of Wyoming, and the United States Geological Survey.

All interested geologists are invited to participate in the conference. Since conference arrangements must be made well in advance, it is imperative that reservations be made as soon as possible. Communications in regard to registration and reservations should be addressed to George Goodin, P. O. Box 545, Casper, Wyoming.

FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS, MAY 27–29

The Field Conference of Pennsylvania Geologists will hold its annual meeting May 27–29 at Lancaster, Pennsylvania. The department of geology of Franklin and Marshall College will be host. The major feature of this year's field excursion will be a trip through southern Lancaster County to study the Martic overthrust problems under the leadership of Professor Ernst Cloos, of the Johns Hopkins University. Other field excursions will include the old Wood chrome mine, Gap nickel mine, other old metal mines, and the flood plain of the Susquehanna River.

For further details, address Richard M. Foose, Department of Geology, Franklin and Marshall College, Lancaster, Pennsylvania.

GEOLOGICAL SYMPOSIUM, UNIVERSITY OF OKLAHOMA, APRIL 5–6

A Subsurface Geological Symposium held at the University of Oklahoma, Norman, April 5–6, included the following program.

1. L. G. Chombart, Schlumberger Well Surveying Corporation, Wichita, Kansas, "Factors Involved in Practical Electric-Log Analysis"
2. J. M. Terry, Lane-Wells Company, Oklahoma City, "Radioactivity Well-Logging Applications in Oil-Well Completions"
3. C. W. Tomlinson, Ardmore, Oklahoma, "Address"
4. John M. Hills, Midland, Texas, "The Microscopic Examination of Oil-Well Samples"
5. P. B. Nichols, The Geolograph Company, Oklahoma City, "The Geolograph Mechanical Well Log: Interpretation and Application of Data"
6. L. B. Meadors, Halliburton Oil Well Cementing Company, Duncan, Oklahoma, "Uses of Drill-Stem Test Data to the Subsurface Geologist"
7. L. G. Chombart, Schlumberger Well Surveying Corporation, Wichita, Kansas, "Technique and Application of Dipmeter and Photoclinometer Surveys"
8. R. W. Wilson, National Lead Company, Baroid, Houston, Texas, "Principles and Applications of Mud-Analysis and Cuttings-Analysis Well Logging"
9. Leo Horvitz, Horvitz Research Laboratories, Houston, Texas, "Geochemical Well Logging"
10. Jack Davies, Halliburton Oil Well Cementing Company, Shawnee, Oklahoma, "Temperature Well Logging"
11. Herbert A. Cook, Dowell Inc., Tulsa, "Determination of Relative Permeabilities in Multi-Zone Wells"
12. Jack Davies, Halliburton Oil Well Cementing Company, Shawnee, Oklahoma, "Caliper Well Logging"
13. R. H. Winn, Halliburton Oil Well Cementing Company, Houston, Texas, "Side-Wall Coring"

A.A.P.G. LECTURE TOUR

HORACE D. THOMAS, State geologist of Wyoming, is following an itinerary requiring a full month as A.A.P.G. lecturer at meetings of the following geological groups.

April	4	Geology Club	University of Wisconsin, Madison
	5	Illinois Geological Survey and University Group	University of Illinois, Urbana
	6	Illinois Geological Society	Fairfield, Illinois
		Indiana-Kentucky Geological Society	
	8	Mississippi Geological Society	Jackson, Mississippi
	11	Tulsa Geological Society	University of Tulsa
	12	Kansas Geological Society	University of Wichita
	13	Dallas Geological Society	Southern Methodist University
	14	Fort Worth Geological Society	Texas Christian University
	15	North Texas Geological Society	Wichita Falls
	18	Houston Geological Society	Houston, Texas
	19	South Texas Geological Society	San Antonio, Texas
	20	East Texas Geological Society	Tyler, Texas
		Shreveport Geological Society	
	22	West Texas Geological Society	Midland, Texas
	25	Panhandle Geological Society	Amarillo, Texas
	26	Rocky Mountain Association of Geologists	Denver, Colorado
	30	New Mexico Geological Society	University of New Mexico, Albuquerque
May	3	Wyoming Geological Association	Casper, Wyoming

GUIDE BOOK, ST. LOUIS CONVENTION FIELD CONFERENCE

The *Guide Book* for the field conference held in connection with the 34th annual meeting of the A.A.P.G. at St. Louis, March 18–19, 1949, may be obtained at the price of $1.25, by writing A.A.P.G. Headquarters, Box 979, Tulsa 1, Oklahoma. The book contains 32 pages, spirally bound in covers, 8½ by 11 inches. The itinerary contains a detailed road log and geological descriptions, including 8 text figures and 4 full-page stratigraphic sections and route map. The routes are in southeastern Missouri and southwestern Illinois, including stratigraphic sections ranging from pre-Cambrian into Mississippian. The route in Missouri, from St. Louis to Cape Girardeau, on the first day, is logged as 189.6 miles. The route in Illinois, from Cape Girardeau to St. Louis, the second day, is 181.6 miles. Trip and book were arranged in cooperation with the State Geological Survey of Illinois, the Illinois Geological Survey, and the Missouri Geological Survey and Water Resources.

M. M. BARLOW has moved from the Kingwood Oil Company to the Champlin Refining Company, Enid, Oklahoma.

R. T. CHAPMAN is engaged in consulting practice at 301 Ardis Building, Shreveport, Louisiana. He was recently in the employ of the Stanolind Oil and Gas Company.

Miss ALICE R. ECKERT and HENRY CARTER REA were married, March 14, in Bellville, Illinois.

WALTER H. BUCHER, professor of geology at Columbia University, New York, spoke on "Fault Patterns and Fault Movements," before the Pacific Section of the Association at Los Angeles, California, March 31.

CHARLES W. FOWLER, JR., died on September 20, 1948, at Tulsa, Oklahoma. He was president of the United Oilwell Service in Caracas, Venezuela. He was 49 years of age. Death was due to a heart attack.

JAMES A. WILSEY, geologist with the Phillips Petroleum Company at Denver, Colorado, died in January.

HAROLD G. JOHNSON, geologist with the Standard Oil Company of Texas, Falfurrias, Texas, has passed away. He was born, February 1, 1923.

HERBERT HOOVER, JR., of Pasadena, California, is president and P. E. FITZGERALD of Tulsa, Oklahoma, is vice-president of United Oilwell Service.

PROFESSIONAL DIRECTORY

CALIFORNIA

CANADA

COLORADO

LOUISIANA

NEW ORLEANS GEOLOGICAL SOCIETY
NEW ORLEANS, LOUISIANA

President - - - - - - - - - Fred S. Goerner
California Company, 1818 Canal Building
Vice-President and Program Chairman - - - - - - - - - - - - - M. N. Broughton
The Texas Company, 1500 Canal Building
Secretary-Treasurer - - - - - H. A. Nystrom
Schlumberger Well Surveying Corporation
452 Canal Building

Meets the first Monday of every month, October-May, inclusive, 12 noon, St. Charles Hotel. Special meetings by announcement. Visiting geologists cordially invited.

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - Claude N. Valerius
Barnsdall Oil Company
427 Ricou-Brewster Building
Vice-President - - - - - Walter F. Hamilton
Gulf Refining Company
Box 1731
Secretary-Treasurer - - - - - - - - R. T. Wade
Schlumberger Well Surveying Corporation
Box 92

Meets monthly, September to May, inclusive, in the State Exhibit Building, Fair Grounds. All meetings by announcement.

LOUISIANA

SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - - - - W. B. Neill
Stanolind Oil and Gas Company
Vice-President - - - - - - Pete Haberstick
Atlantic Refining Company
Secretary - - - - - - - - James M. Whatley
Union Sulphur Company, Sulphur, La.
Treasurer - - - - - - - - - Bert C. Timm
Magnolia Petroleum Company

Meetings: Dinner and business meetings third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Special meetings by announcement. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - - W. A. Kelly
Michigan State College
East Lansing
Vice-President - - - - - - Ralph G. Hubman
The Texas Company
Mt. Pleasant
Secretary-Treasurer - - - - - B. T. Sandefur
Michigan State College
East Lansing
Program Chairman - - - - - - - Gus Sanger
Pure Oil Company
Clare

Meetings: Monthly, November through May, at Michigan State College, East Lansing, Michigan. Informal dinners at 6:30 P.M. Papers follow dinner. Visitors welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - - - R. D. Sprague
Sinclair Wyoming Oil Company
Vice-President - - - - - - - E. T. Monsour
Consultant, Box 2571, West Jackson
Secretary - - - - - - - - - George W. Field
Cities Service Oil Company, 1407 Tower Building
Treasurer - - - - - - - - - Charles E. Buck
Skelly Oil Company, 100 East Pearl Building

Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., The Creole Room, LeFleur's Restaurant, Jackson, Mississippi. Visiting geologists welcome to all meetings.

NEW YORK

EASTERN SECTION AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
NEW YORK, NEW YORK

President - - - - - - - - Hollis D. Hedberg
Gulf Oil Corp., 17 Battery Place
Vice-President - - - - - Douglas A. Greig
Standard Oil Co., (N.J.), 30 Rockefeller Plaza
Treasurer - - - - - - - - - Marshall Kay
Department of Geology, Columbia University
Secretary - - - - - - - Godfrey F. Kaufman
Standard-Vacuum Oil Co., 26 Broadway,
Room 1556

Meetings by announcement to members. Visiting geologists and friends cordially invited.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - - I. Curtis Hicks
Phillips Petroleum Company

Vice-President - - - - - - Earl Westmoreland
Seaboard Oil Company

Secretary-Treasurer - - - - - - Frank Millard
Schlumberger Well Surveying Corp., Box 747

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - Robert R. Wheeler
Consultant, 1216 Petroleum Building
Vice-President - - - - - - - - L. R. Wilson
Carter Oil Company
1300 Apco Tower
Secretary - - - - - - - - - - - John Janovy
Tide Water Associated Oil Company
918 Hales Building
Treasurer - - - - - - - - Elwyn R. Owens
Phillips Petroleum Company

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every second and fourth Thursday of each month, at 12:00 noon, Y.W.C.A.

OKLAHOMA

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - - - - Fred J. Smith
Sinclair Prairie Oil Company
Box 991, Seminole

Vice-President - - - - - - Doyle M. Burke
The Texas Company
Box 1007, Shawnee

Secretary-Treasurer - - - - - Marcelle Mousley
Atlantic Refining Company, Box 169
Shawnee

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - - - - Jerry E. Upp
Amerada Petroleum Corporation, Box 2040

1st Vice-President - - - - - W. Reese Dillard
Consultant, Box 2204

2d Vice-President - - - - John M. Nash
Shell Oil Company, Box 1191

Secretary-Treasurer - - - - - - - - Noel Evans
Consultant, 1510 Philtower Building

Editor - - - - - - - - - - John C. Maher
U. S. Geological Survey, Federal Building

Business Manager - - - - - - - V. L. Frost
Ohio Oil Company, Thompson Building

Meetings: First and third Monda s, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Lorton Hall. Luncheons: Every Friday (October-May), Chamber of Commerce Building.

PENNSYLVANIA

PITTSBURGH GEOLOGICAL SOCIETY
PITTSBURGH, PENNSYLVANIA

President - - - - - - - - - - John T. Galey
Independent, Box 1675

Vice-President - - - - - - - W. B. Robinson
Gulf Research and Development Company
Box 2038

Secretary - - - - - - - - - James C. Patton
Equitable Gas Company
610 Wood St.

Treasurer - - - - - - - - - Sidney S. Galpin
Peoples Natural Gas Company
545 William Penn Place

Meetings held each month, except during the summer. All meetings and other activities by special announcement.

TEXAS

ABILENE GEOLOGICAL SOCIETY
ABILENE, TEXAS

President - - - - - - - - - - - J. R. Day
Pan American Production Company

Vice-President - - - - - David M. Grubbs
Drilling and Exploration Company

Secretary-Treasurer - - - - - C. S. Noland
Skelly Oil Company

Meetings: 2d Thursday of each month, 7:30 P.M., Wooten Hotel.

TEXAS

CORPUS CHRISTI GEOLOGICAL SOCIETY
CORPUS CHRISTI, TEXAS

President - - - - - - - - H. D. McCallum
Humble Oil and Refining Company, Box 1271

Vice-President - - - - - Norman D. Thomas
Pure Oil Company

Secretary-Treasurer - - - - - James D. Burke
Seaboard Oil Company of Delaware, Box 601

Regular luncheons, every Thursday, Terrace Annex Room, Robert Driscoll Hotel, 12:00. Special night meetings by announcement.

DALLAS GEOLOGICAL SOCIETY
DALLAS, TEXAS

President - - - - - - - - - John T. Rouse
Magnolia Petroleum Company
P.O. Box 900

Vice-President - - - - - - - H. V. Tygrett
The Atlantic Refining Company
P.O. Box 2819

Secretary-Treasurer - - - - Gilbert P. Moore
Consulting, 501 Continental Building

Executive Committee - - - - - Edgar Kraus
Atlantic Refining Company
Box 2819

Meetings: Monthly luncheons and night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

President - - - - - - - - - P. S. Schoeneck
Atlantic Refining Company
205 Manziel Building

Vice-President - - - - - - - - - J. C. Price
Magnolia Petroleum Company
Box 780

Secretary-Treasurer - - - - - - G. C. Clark
Stanolind Oil and Gas Company
Box 660

Luncheons: Each week, Monday noon, Blackstone Hotel.

Evening meetings and programs will be announced. Visiting geologists and friends are welcome.

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - - - - F. H. Schouten
Stanolind Oil and Gas Company
Box 1410

Vice-President - - - - - - H. C. Vanderpool
Texas Pacific Coal and Oil Company
Box 2110

Secretary-Treasurer - - - - - Thomas Nichols
Rowan Oil Company
Commercial Standard Building

Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

TEXAS

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - - - - A. F. Childers
Gulf Oil Corporation, Box 2100
Vice-President - - - - - Hershal C. Ferguson
Consultant, 935 Esperson Building
Secretary - - - - - - - - - - R. R. Rieke
Schlumberger Well Surveying Corporation
Treasurer - - - - - - - Mary L. Holland
Stanolind Oil and Gas Company

Regular meeting held the second and fourth Mondays at noon (12 o'clock), Mezzanine floor, Rice Hotel. For any particulars pertaining to the meetings write or call the secretary.

PANHANDLE GEOLOGICAL SOCIETY
AMARILLO, TEXAS

President - - - - - - - - - G. E. Hatton
Phillips Petroleum Company, Box 1761
Vice-President - - - - - - Robert F. Herron
Oil Development Company, 900 Polk St.
Secretary-Treasurer - - - - - Robert B. Totten
Sun Oil Company, Box 46

Meetings: Luncheon 1st and 3rd Wednesdays of each month, 12:00 noon, Herring Hotel. Special night meetings by announcement.

TEXAS

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS

President - - - - - - - - - W. T. Schneider
Honolulu Oil Corporation, Box 1391
Vice-President - - - - - Ralph D. Chambers
Continental Oil Company, Box 431
Secretary - - - - - - - - - Jesse A. Rogers
The Texas Company, Box 1270
Treasurer - - - - - - - John V. Norman, Jr.
Forest Oil Corporation, Box 1821

Meetings will be announced.

WYOMING

WYOMING GEOLOGICAL ASSOCIATION
CASPER, WYOMING
P.O. Box 545

President - - - - - - - - - Jed B. Maebius
Gulf Oil Corporation, Box 1971
1st Vice-President - - - - Emmett E. Schieck
Morton Oil Company, Box 1970
2d Vice-President (Programs) - Donald E. Edstrom
British-American Oil Producing Company, Box 620
Secretary - - - - - - - - J. B. Headley, Jr.
Atlantic Refining Company
Treasurer - - - - - - - - - George L. Goodin
Petroleum Information, Inc.

Informal luncheon meetings every Friday, 12 noon, Townsend Hotel. Visiting geologists welcome. Special meetings by announcement.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - - - - J. J. Russell
Independent Geologist, 907 Staley Building
Vice-President - - - - - Joseph W. McDonald
Shell Oil Company, Inc., Box 2010
Secretary-Treasurer - - - - Ralph H. McKinley
Panhandle Producing and Refining Company, Box 1191

Meetings: Luncheon 1st and 3d Wednesdays of each month, 12:00 noon, Y.W.C.A. Evening meetings by special announcement. Visiting geologists and friends are cordially invited to all meetings.

SOUTH TEXAS GEOLOGICAL SOCIETY
SAN ANTONIO, TEXAS

President - - - - - - - - - Paul B. Hinyard
Shell Oil Company
2000 Alamo National Building
Vice-President - - - - - - - - - J. Boyd Best
Ohio Oil Company
Secretary-Treasurer - - - Louis H. Haring, Jr.
Stanolind Oil and Gas Company

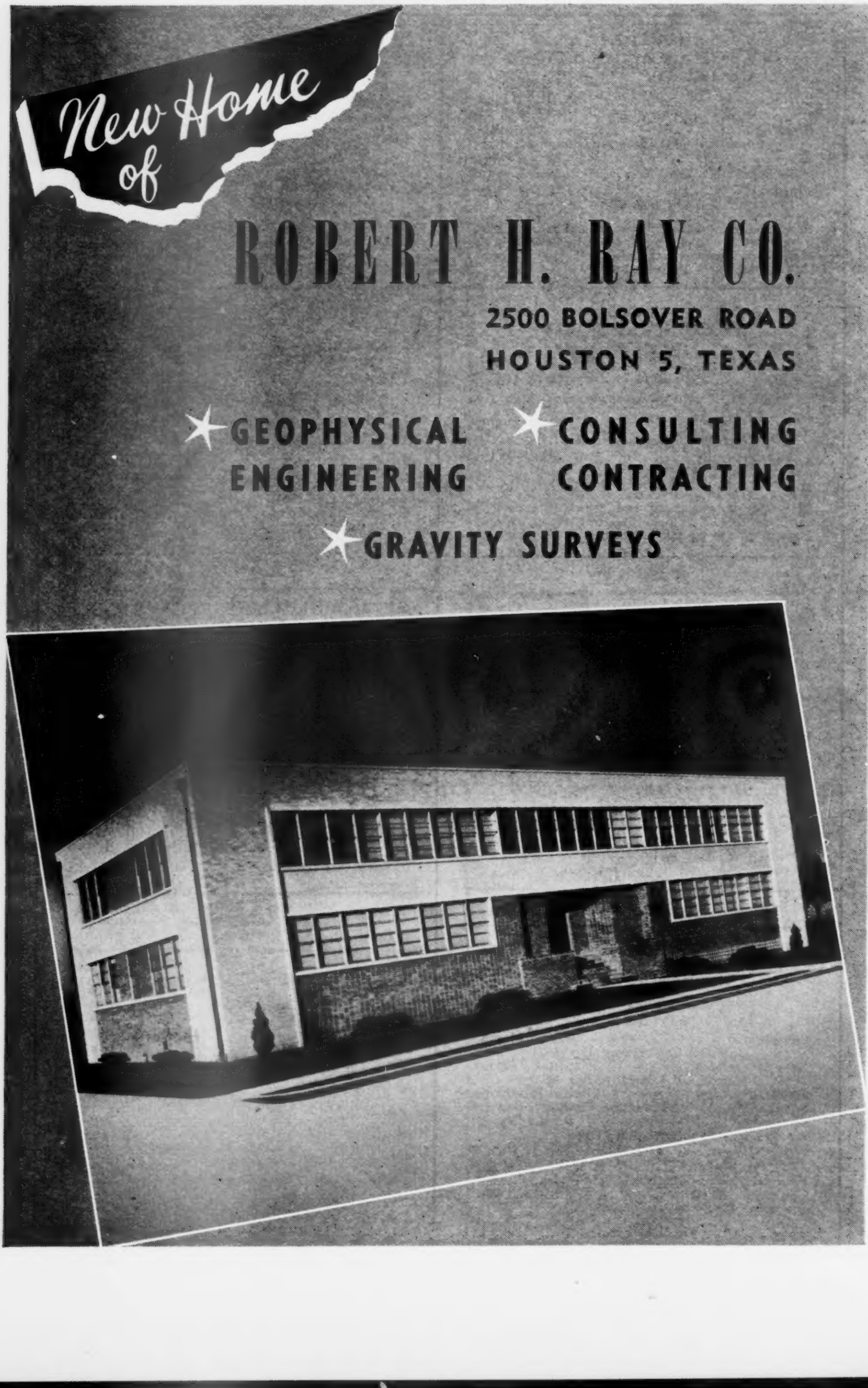
Meetings: One regular meeting each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

WEST VIRGINIA

APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA
P.O. Box 2605

President - - - - - - - - - - W. B. Maxwell
United Fuel Gas Company, Box 1273
Vice-Pres., Northern Div. - - - Robert S. Hyde
545 William Penn Place, Pittsburgh, Pa.
Vice-Pres., Central Div. - - - George H. Hall
Southeastern Gas Corp., Charleston, W.Va.
Vice-Pres., Kentucky Div. - - - Paul Dufendach
Kentucky-West Virginia Gas Co., Ashland, Ky.
Secretary-Treasurer - - - - G. L. Ballentine
268 Oakwood Road, Charleston, W.Va.
Editor - - - - - - - - - - - - W. T. Ziebold
Thomas Circle Road, Charleston, W.Va.

Meetings: Second Monday, each month, except June, July and August, at 6:30 P.M., Daniel Boone Hotel.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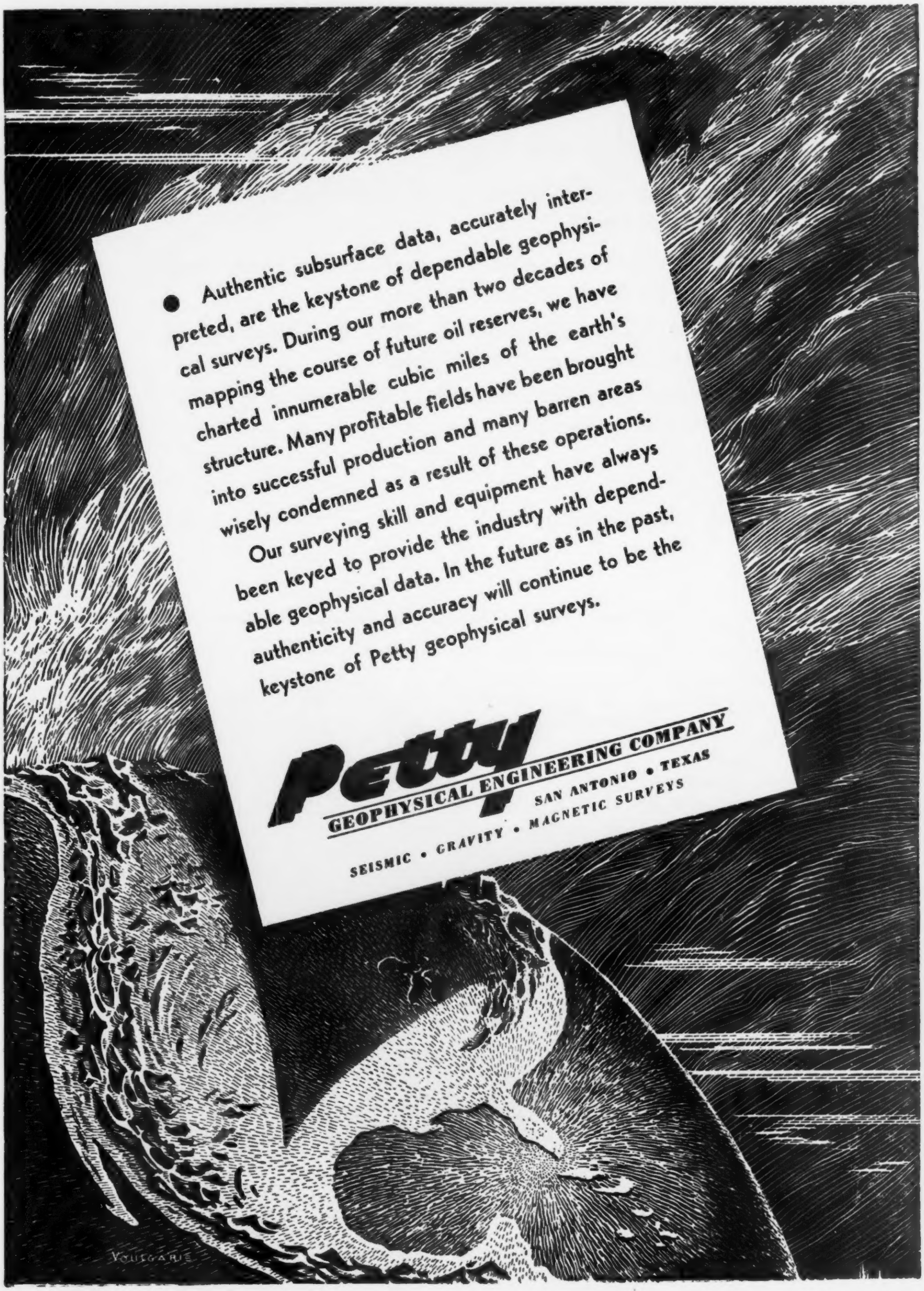

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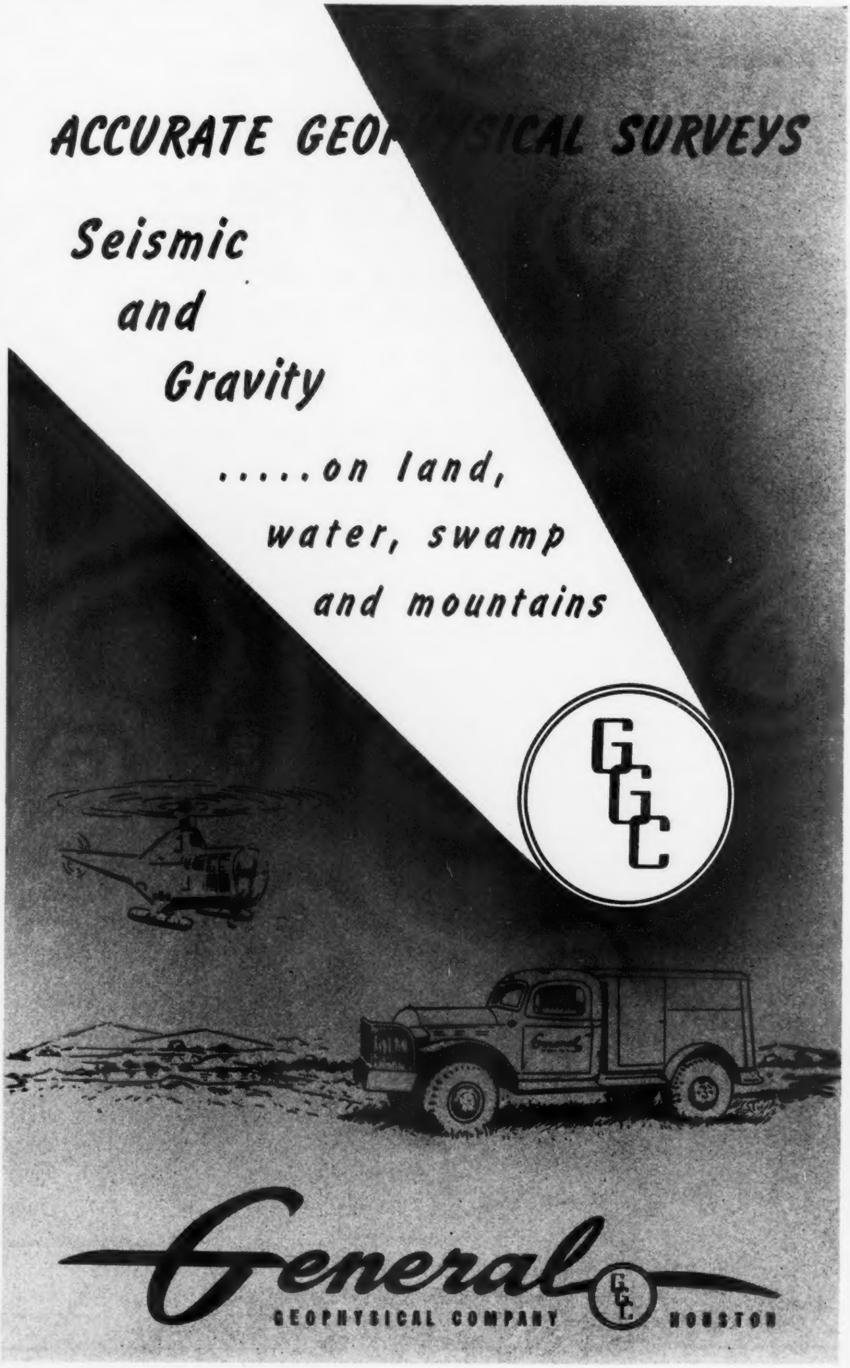
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